A DICTIONARY OF ELECTRICAL ENGINEERING

ELECTRIC CANAL TRACTOR (WOOD SYSTEM)

[*Frontispiece.*

A DICTIONARY OF ELECTRICAL ENGINEERING

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With the Co-operation of

EMINENT SPECIALISTS

VOLUME I

PHILADELPHIA

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PREFACE

In view of the large number of special articles included in the present work, and of the extent and nature of the practical information accompanying the greater part of the definitions, it could hardly have been deemed inappropriate had the work been termed an Encyclopædia. A large amount of specialised information has been included in its pages, and by taking advantage of the copious cross references, the reader may, in many instances, acquaint himself with the principles of particular sections of electrical engineering fully as readily as would be practicable with special textbooks dealing with the sections in question. Indeed the sidelights thrown on any subject by the definitions coming under related sections will often be found to afford means for acquiring a broader grasp of the subject than can generally be acquired by the more usual process of consulting in the first instance a specialised textbook.

The chance juxtaposition, in virtue of alphabetical arrangement, of discussions of related phenomena from the points of view of independent specialists in different fields, is inevitably instructive to workers in each of the special fields. Oscillatory phenomena, for example, are regarded by the laboratory investigator, the power-transmission engineer, and the telephone engineer from three independent standpoints, and the aspects emphasised by each of these classes of specialist are mutually helpful. Consequently the allocation of the work amongst twenty-two contributors has had advantages far outweighing the obvious advantage of expedition, and the editor has in many instances purposely refrained from deleting or condensing overlapping definitions, as he considers that independent efforts at a clear presentation of a principle, more especially when these efforts emanate from minds engaged on different applications of the principle, afford to the reader an unrivalled means of attaining to a broad comprehension of the principle. The reader will be prepared, after his preliminary study of a subject by means of the entries in this dictionary, to carry his enquiries further into the matter by means of the textbooks and articles to which reference is freely made throughout the dictionary. Lists of the books, papers, and articles to which reference is made are given at the end of the work.

A perusal of the list of contributors will show that the various branches have been handled by practical specialists of good professional standing, and, in addition to these contributors, the editor has been most generously assisted by many of his friends with criticisms, suggestions, and the occasional contribution of additional definitions and data. Among such instances of friendly criticism, and of the supply of further data, the editor wishes to take the opportunity of acknowledging his thanks to Mr. Sam Mavor (Mining), Messrs. Franklin Punga and Val A. Fynn (Single-phase motors), Messrs. Frank Holden and Wallis-Jones (certain electrical instruments for special purposes), Mr. Henry A. Mavor (Spinner motors for ship propulsion), Mr. Arthur Jacob (Aluminium), Mr. A. C. Jolley (Electrical Testing), Mr. C. F. Tweney, late Librarian and Secretary, Putney Public Library (for numerous valuable suggestions), and Mr. H. E. Yerbury, Chief Engineer of the Sheffield Corporation Tramways, for providing certain illustrations.

Messrs. Whittaker notably, and also other publishers of technical books and periodicals, as well as various manufacturers, including The Cambridge Scientific Instrument Co., Ltd.; Callender's Cable and Construction Co., Ltd.; Messrs. Mirrlees, Bickerton, & Day, Ltd.; The Mirrlees Watson Company, Ltd.; Messrs. Johnson & Phillips, Ltd.; The Lancashire Dynamo and Motor Co., Ltd.; and the British Thomson-Houston Co., Ltd., have extended the editor the courtesy of permitting him to reproduce from their publications certain appropriate illustrations. Nevertheless, of the 700 illustrations a large proportion are original, and have been made expressly for the purpose of this work.

Because of these various features the editor is confident that the work will fulfil purposes far exceeding the prosaic though important functions of a dictionary. Nevertheless, in view of the activity in defining electrical terms which has lately been evinced in several quarters, the dictionary feature of the work is especially timely. The International Electrotechnical Commission, for instance, has appointed Committees on Nomenclature. Of these Committees the British section has been especially active, and has already issued to the technical press a considerable number of preliminary definitions. The editor has included these definitions, which will be found printed in small type in their proper alphabetical order, and followed by the letters I.E.C. Just as the present work is passing through the press, and consequently too late to be included, there have been published (July, 1910) some seventy definitions proposed by the American Electric Light Association, and (Proc.A.I.E.E. for August, 1910) several dozen revised definitions by the Standards Committee of the American Institution of Electrical Engineers. The Engineering Standards Committee's reports comprise occasional definitions, of which a few have been included, as also a large number of definitions published in 1907 in the Standardisation Rules of the American Institute of Electrical Engineers. Further definitions are quoted from the 1907 Wiring Rules of the British Institution of Electrical Engineers; from the 1908 Home Office Regulations for Electricity in Factories and Workshops; from the 1909 Electric Lighting Act; from the Standardisation Rules of the Verband Deutscher Elektrotechniker (V.D.E.); and from the Phœnix Fire Office Rules for Electric Light and Electric Power Installations. These definitions are in most cases merely added after the definition and article supplied by the contributor. It must be confessed that, considering the broad composition of these Congresses, Committees, and other bodies, the results yielded, so far as relates to progress in definition, are still decidedly meagre. Nevertheless, they reflect the need for work on these lines, and thus support the independent judgment of the publishers in bringing out the present work.

In the course of his work on this dictionary the editor has become more deeply convinced than ever before that engineers should make an early stand against the continued use of inappropriate words and phrases. It is not practicable on the present occasion to deal at length with the subject, and it must suffice to cite a very few instances. Let us take the term "alternating-current voltage". If we try to improve the term, there pass through our minds a confusing number of alternatives, such as "alternating-current pressure", "alternating-current tension", "alternating electric pressure", and "alternating electric tension". Voltage, pressure, and tension appear to be used as synonymous, and to a fairly equal extent. Amperage would not be countenanced, and yet it is not evident why voltage should be considered less objectionable than amperage. It is hard to imagine that the term "alternating amperage pressure" would ever be employed, and yet it is, as regards derivation, no more absurd than "alternating-current voltage". Very many equally incongruous phrases are widely employed in engineering literature. These are constantly being built upon, and are rapidly becoming more and more cumbersome. The old question of the relative merits of the terms "continuous current" and "direct current" is still unsettled. There is little to choose between the two terms; nevertheless it should be practicable definitely to adopt one or the other. The term "continuous current" has been selected in the present work, and in addition to the support of such authorities as Prof. Silvanus Thompson and Prof. Gisbert Kapp, there is the considerable advantage that it conforms with the terms employed in the French and Italian languages. While some engineers speak of "alternating current", others prefer "alternate current".

The author's personal opinion is that in practical engineering work much less stress could with advantage be laid on the word "current", and that we should more frequently than at present employ the terms "continuous electricity" and "alternating electricity" notwithstanding that some slight theoretical inconsistency is, from the physicist's standpoint, involved in the plan. For the engineer, these theoretical objections are outweighed by the great practical convenience and expressiveness of the terms "continuous electricity", "alternating electricity", "single-phase electricity", and "polyphase electricity". The editor finds no practical objection sufficient to offset the great advantage of regarding electricity as a form of energy, and continuous and alternating electricity as two forms of electricity. Following up this subdivision, alternating electricity has in turn various forms, such as "single-phase electricity" and "polyphase electricity", while polyphase electricity may be of the two-phase or of the three-phase variety. When in *commercial* work the term "current" is employed, it is really *energy* (in the form of electricity) which is almost always meant. A consumer does not pay for the current, or for the pressure, or for the time, but for *electricity* (a form of energy), which (when in the form known as continuous, as also, under certain conditions, when in other forms) is equal to the product of these three quantities—current, pressure, and time. Practically all electrical engineers, when they employ the word "electricity" in their everyday intercourse, are alluding to a form of energy. This use of the word is now firmly established, and it is too late to revert to earlier notions and restrict electricity to the meaning ascribed to it by physicists.

The International Electrotechnical Commission, which has spent several years in the endeavour to complete a list of definitions of electrical terms, has now dealt with the first five letters of the alphabet. It appears from the proceedings at an informal meeting of the Commission held at Brussels in August, 1910, that it has been provisionally decided to abandon the plan of taking up each term as it occurs in the order of the alphabet, and to adopt the method of dealing with the terms in groups, assigning groups of related terms to sub-sections. This is the method which the present editor adopted at the outset of his work on this dictionary. Each contributor has, as a rule, dealt with those terms with which he has become most familiar in the course of his professional work.

As instances of subjects of special present interest, the editor would call attention to the articles and definitions dealing with Electric Lighting, Photometry, Standards of Light, Radiation, Thermo-Electricity, Electric Furnaces, Electro-chemistry and Electro-metallurgy, Electromagnetic Separation of Ores, Electric Welding, Electricity in Mining, Electric Coal-cutters, Electric Cranes and Lifts, the Starting and Speed-control of Motors, Single-phase Motors, Polyphase Motors with Commutators, Relays and Remote-control Devices, Potential Regulators, Transformers, Rectifiers, Lightning Arresters, Transmission Lines, Central Stations, Circuit-breakers, Switchgear, Rheostats, Electricity Meters and Measuring Instruments, Systems of Charging for Electricity, Wireless Telegraphy and Telephony, Measurements of Mechanical and Electrical Power, Magnetic Measurements, Ventilation of Electrical Machinery, Phenomena of Electric Waves, and Oscillographs.

H. M. H.

Note.—For convenience of reference the pagination of the second volume is continuous with that of the first.

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LIST OF ABBREVIATIONS

USED THROUGHOUT THE DICTIONARY

ac	alternating current.
A.I.E.E.	American Institute of Electrical Engineers.
amp	ampere.
amp hr	ampere-hour.
Am. Phys. Soc.	American Physical Society.
Ann. der Physik.	Annalen der Physik.
atm	atmosphere.
ats	ampere turns.
AWG	American Wire Gauge.
bdf	break-down factor.
bhp	brake horse power.
B.O.T.	Board of Trade.
B.P.	British Patent.
B Th U	British Thermal Unit.
BTU	Board of Trade Unit.
BWG	Birmingham Wire Gauge.
cc	continuous current.
c emf	counter electromotive force.
cgs	centimeter-gram-second.
cm	centimeter.
cp	candle power.
cu	cubic.
Deutsch. Phys. Gesell.	Deutsche Physikalische Gesellschaft.
dm	decimeter.
dp	double pole.
D.R.P.	Deutsches Reichs Patent.
dt	double throw.
ehp	electrical horse power; extra high pressure.
eht	extra high tension.
Elec.	'Electrician'.
Elec. Eng.	'Electrical Engineering'.
Elec. Engr.	'Electrical Engineer'.
Elec. Rev.	'Electrical Review'.
Elec. Times	'Electrical Times'.
Elec. World	'Electrical World'.
emf	electromotive force.
Eng.	'Engineering'.

Engr.	'Engineer'.
E.T.Z.	'Elektrotechnische Zeitschrift'.
fig.	figure.
ft	foot or feet.
ft lb	foot-pound.
g	gram.
gal	gallon.
g deg cal	gram-degree calorie.
hf	high frequency.
hp	horse-power.
hp hr	horse-power-hour.
h pr	high pressure.
hr	hour.
ht	high tension.
I.E.C.	The 1908 Sub-committee on Nomenclature of the British Committee of the International Electrotechnical Commission.
I.E.E.	Institute of Electrical Engineers.
ihp	indicated horse power.
in	inch.
IWG	Imperial Wire Gauge.
Journ.I.E.E.	'Journal of the Institution of Electrical Engineers'.
kg	kilogram.
kg cal	kilogram calorie.
kg m	kilogram-meter.
km	kilometer.
km phps	kilometers per hour per second.
kva	kilovolt-ampere.
kw	kilowatt.
kw hr	kilowatt-hour.
lb	pound.
lf	low frequency.
l pr	low pressure.
lt	low tension.
m	meter.
mfd	microfarad.
mg	milligram.
min	minute.
m kg	meter-kilogram.
ml phps	miles per hour per second.
mm	millimeter.
mmf	magnetomotive force.
mphps	meters per hour per second.
pd	potential difference.
pf	power factor.
Phys. Rev.	'Physical Review'.
Proc.A.I.E.E.	'Proceedings of the American Institute of Electrical Engineers'.
Proc.I.C.E.	'Proceedings of the Institute of Civil Engineers'.
Proc.I.M.E.	'Proceedings of the Institute of Mechanical Engineers'.
Proc. Roy. Soc.	'Proceedings of the Royal Society'.

Ref.	References.
rms	root mean square.
rpm	revolutions per minute.
rps	revolutions per second.
sec	second.
Soc. Int. Elect.	'Bulletin de la Société Internationale des Electriciens'.
sp	single pole; single phase.
sq	square.
st	single throw.
SWG	Standard Wire Gauge.
tp	triple pole.
Trans.	Transactions.
V.D.E.	Verband Deutscher Elecktrotechniker.
V.D.I.	Verband Deutscher Ingenieure.
w	watt.
w hr	watt-hour.
wpcp	watts per candle power.
yd	yard.

LIST OF PLATES

VOLUME I

A DICTIONARY OF ELECTRICAL ENGINEERING

A

Abscissæ. See CURVES.

Absolute Calibration. See CALIBRATION.

Absolute Electrometer. See ELECTROMETER.

Absolute Galvanometer. See GALVANOMETER.

Absolute Potential. See POTENTIAL, ELECTRIC.

Absolute Unit. See UNIT, ABSOLUTE.

Absolute Unit of Current. — The absolute cgs unit of current in the electromagnetic system is a current of such value that when flowing in a circular conductor of 1 cm radius it produces at the centre of the circle a magnetic force corresponding to a density of 2π lines per sq cm, the conductor being in air. The value of this current is 10 amp. See AMPERE.

Absorption, Coefficient of. See COEFFICIENT OF ABSORPTION.

Absorption, Electrical. — When an electrical condenser is charged, a certain portion of the charge is absorbed in the dielectric. On discharge, this portion is only gradually given up. The phenomenon is very marked in cables. It varies considerably in different dielectrics.

Absorption, Power. See POWER ABSORPTION.

Absorption Dynamometer. See DYNAMOMETER.

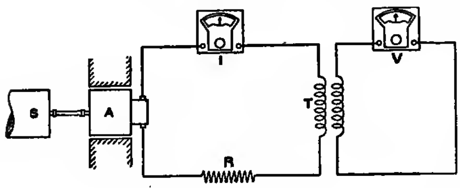
Ac, the preferable abbreviation for *alternating current* (which see).

Acceleration, the rate of change of velocity, preferably expressed in m psps, but also often expressed in km phps, ft psps, miles phps, as well as in other units of length and time. The velocity may be *increasing*, in which case the acceleration is 'positive'; or *decreasing*, in which case the acceleration is 'negative'. The latter is sometimes termed *deceleration.* The rapid acceleration of cars and trains is a very valuable feature secured by electric traction. The equivalent values of acceleration in various units are given in the following table:—

Acceleration expressed in mpsps	**0·112**	**0·224**	**0·336**	**0·447**	**0·560**	**0·671**	**0·784**	**0·895**	**1·00**	**1·12**	**1·23**	**1·34**
Acceleration expressed in km phps	0·402	0·805	1·21	1·61	2·01	2·42	2·82	3·22	3·62	4·02	4·42	4·83
Acceleration expressed in miles phps	**0·250**	**0·500**	**0·750**	**1·00**	**1·25**	**1·50**	**1·75**	**2·00**	**2·25**	**2·5**	**2·75**	**3·00**
Acceleration expressed in ft psps	0·366	0·733	1·10	1·47	1·83	2·20	2·56	2·93	3·30	3·67	4·04	4·42

Accelerometer, an instrument used for measuring the rate of acceleration of cars, trains, or other conveyances when starting or stopping.

In the *electric accelerometer* illustrated a cc dynamo A, excited either by permanent magnets or by a constant current, is mechanically coupled to the axle S, so that it shall be driven at a speed proportional to that of the vehicle. The brushes are coupled, through a non-inductive resistance R and a centre-zero, moving-coil ammeter I, to the primary of a static transformer T. The secondary is connected to a centre-zero, moving-coil voltmeter V. The reading of the



Electric Accelerometer

S, Wheel shaft. A, Cc dynamo with constant excitation. R, Non-inductive resistance. T, Static transformer. I, Ammeter. V, Milli-voltmeter.

ammeter in the primary is then proportional to and indicates the actual speed of the vehicle, and that of the voltmeter in the secondary indicates the rate of change of the current, and hence is proportional to the acceleration of the vehicle. The transformer should have a straight-line saturation curve.

Accumulated Static Charge, see STATIC DISTURBANCES.

Accumulator, a group of cells whose plates are capable of regeneration after exhaustion. The regeneration is accomplished by passing an electric current through the cells in a direction opposite to that of the flow on discharge. An accumulator is often termed a *storage battery*. A component cell of an accumulator is sometimes termed an *accumulator cell*, or a *storage cell* or *secondary cell*, or *secondary battery*. The term *secondary battery* should, however, preferably be reserved for designating a group of cells, *i.e.* an accumulator. For private electric lighting plants the use of an accumulator is almost universal, as without it, it is necessary to have plant running whenever light is required. In central lighting stations an accumulator is employed for relieving the generators of short peaks, and for taking the load when it falls below an economical load for the generating plant. In electric tramway and railway service, an accumulator in conjunction with an automatic reversible booster maintains a constant load on the generator. An accumulator may thus be employed to reduce the amount of plant necessary to handle a fluctuating load. For telephone and telegraph service the accumulator is rapidly replacing the primary battery.

['*Accumulator*, an electric cell consisting of plates or of grids in an electrolyte, of such a character that the electrical energy supplied to it is converted into chemical energy (a process called *charging*). The chemical energy can be reconverted into electrical energy (a process called *discharging*). Sometimes called a *storage cell* or a *secondary cell*. Several accumulators connected together in one circuit are sometimes called a *secondary battery*.'—I. E. C.]

The great majority of accumulators are of the lead type, and may be termed *lead accumulators*. A number of lead accumulators are described below, and these descriptions are followed by reference to the *alkali type of accumulator*, of which *Edison's nickel-steel accumulator* is the only one which can be said to have been brought to a commercial stage.

LEAD ACCUMULATORS.—These are usually divided into two classes—*Faure* or '*pasted*' cells, and *Planté* or '*formed*' cells. The first class includes all those employing plates in which the active material is applied to a grid or support in the form of spongy lead, or of a lead salt, or in which the active material is first prepared in any suitable shape, the supporting grid being afterwards cast round it. The second class includes all those employing plates in which the active material is formed on the actual surface of the support itself by electrochemical means (see also ACCUMULATOR PLATES). The plates are immersed in dilute sulphuric acid (see ACCUMULATOR ACID), and may be connected either to the source of energy from which they are charged, or to the circuits to which they are desired to supply energy.

TUDOR ACCUMULATOR, a make of lead accumulator in which the positive plate is of the Planté type, cast with a series of fine vertical ribs to increase the surface of the plate, and occasional horizontal ribs to increase its mechanical strength. The negative plate is of the pasted type. It is made in two halves, riveted together after the insertion of the active material. In figs. 1 and 2 Tudor positive and negative plates are illustrated.

D. P. ACCUMULATOR, an accumulator employing plates of the same general de-

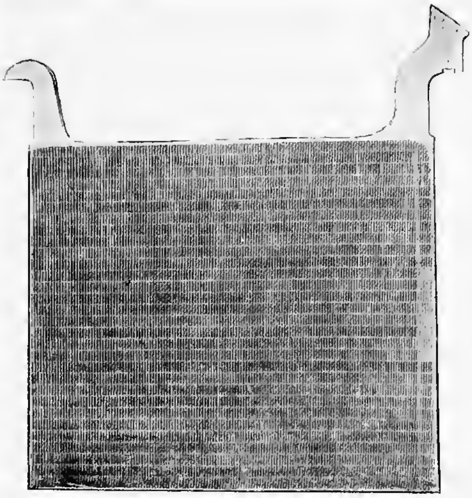


Fig. 1. TUDOR POSITIVE PLATE

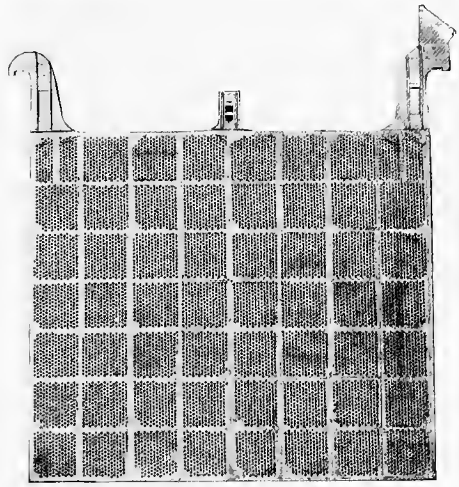


Fig. 2. TUDOR NEGATIVE PLATE

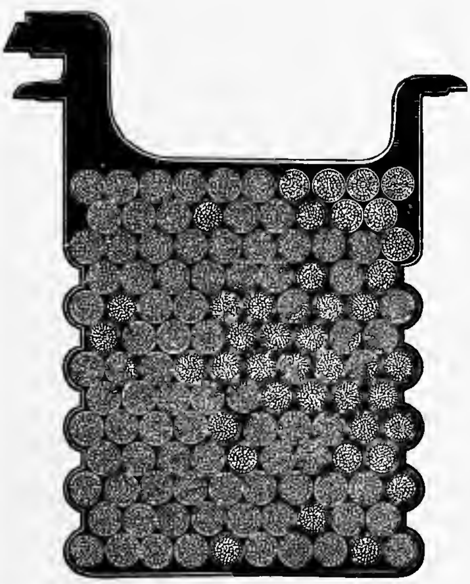


Fig. 3. CHLORIDE POSITIVE PLATE

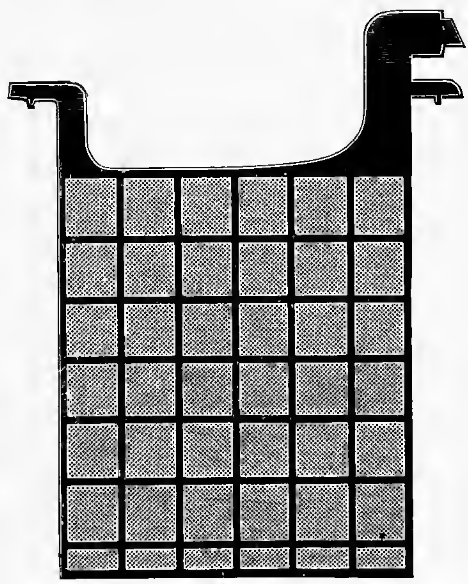


Fig. 4. CHLORIDE NEGATIVE PLATE

ACCUMULATOR PLATES

[To face p.

scription as that employed in the Tudor Accumulator.

CHLORIDE ACCUMULATOR, a make of lead accumulator in which the positive plates are of the Planté type, but 'built up' instead of being cast. In this type of accumulator the active material consists of corrugated lead spirals arranged in an antimony-lead grid in holes cast countersunk on both sides. The frame of the negative plate, which is of the pasted type, is made in two halves, riveted together after the insertion of the active material. Wood diaphragm separators are employed with this type of cell. Chloride positive and negative plates are illustrated in figs. 3 and 4.

ELECTRICAL POWER STORAGE ACCUMULATOR, a lead accumulator originally employing a pasted type of plate, now made both as a pasted plate and as a Planté type. Owing to the tapering of the aperture toward the centre, the active material is locked in place. The accumulator is widely known as of the '*E.P.S.*' type, the full name being rarely used.

EXIDE ACCUMULATOR, a type of accumulator designed for electric vehicle work. Both the positive and the negative plates are of the pasted type. The active material is arranged in the form of long pencils, in which the ribs of the grid are embedded. The wood separators employed with this type of cell are a distinctive feature.

HATCH ACCUMULATOR, a modification of the pasted type of accumulator, in which the active materials are contained within slabs of highly porous earthenware, the sides of which are provided with receptacles. The earthenware receptacles are assembled with plain sheets of lead between them to act as conductors, the sheets being alternately positive and negative; thus the earthenware slabs have positive material on one side and negative on the other.

LITHANODE ACCUMULATOR.—The active mass is composed of very hard material. Originally a thin platinum backing was employed as conductor, but this is now replaced by a hard antimonial lead frame for the positive plates, and by a network of wires in a thin antimonial frame for the negative plates.

ZINC-LEAD ACCUMULATOR.—Much experimenting has been done with an accumulator having a zinc negative plate and a lead peroxide positive with sulphuric acid electrolyte. The principal difficulties lie in obtaining an even deposit of zinc when the cell is being charged, and in preventing local action on the zinc electrodes during the periods when the cell is not in use. The emf of the cell is about 2·2 to 2·3 volts.

ALKALI ACCUMULATOR.—In certain types of accumulator an electrolyte of caustic alkali is used in place of the usual acid. In these accumulators the alkali does not enter into combination with the active material, and for this reason does not vary in strength during charge or discharge.

EDISON'S NICKEL-STEEL ACCUMULATOR.—The positive active material is finely divided nickelic oxide. The negative active material is finely divided iron. The electrolyte is a 10-per-cent to 50-per-cent solution of caustic potash (or soda) in water.

Special precautions are taken to ensure the requisite degree of fineness in the active materials. During discharge the iron becomes oxidised and the nickel oxide becomes reduced to a lower oxide, the opposite effect taking place on charging. The electrolyte is unacted upon chemically, since the reaction is merely a transference of oxygen from one electrode to another. Consequently the specific gravity of the electrolyte remains constant. Elaborate means are taken to provide efficient supports for the active materials, and there are special vents to prevent absorption by the caustic alkali of carbonic acid from the air, at the same time allowing the egress of the gases during charge. See also on p. 183.

TRACTION ACCUMULATOR, an accumulator designed with a view to giving maximum capacity with minimum weight, in order that the complete weight of the electric vehicle propelled by the energy supplied from the accumulator may be kept as low as possible. See also 'Ampere Hours per Kilogram of Plate' under ACCUMULATOR PLATES.

LINE ACCUMULATOR, an accumulator arranged in connection with an electric-power supply system, and located at some distance from the main source. It is employed for the purpose of absorbing the fluctuations of load, which are thus dealt with locally. This results in a considerable saving in the size of copper cables and in the amount of generating plant necessary. In fig. 5 an instance is given of the comparative costs claimed for an eight-mile tramway scheme 'with' and 'without' a storage battery.

COMPARATIVE ESTIMATE OF COST

Without Line Accumulator

Cable	£9673	0	0
Plant, 200 kw.	3200	0	0
	£12,873	0	0

With Line Accumulator

Cable	£3956	0	0
Plant, 150 kw.	2400	0	0
Battery	760	0	0
	£7116	0	0

ANNUAL CHARGES (Copper Depreciation omitted)

Interest on £12,873 at 6 per cent ...	£772	0	0
Depreciation on £3200 at 5 per cent ...	160	0	0
	£932	0	0

Interest on £7116 at 6 per cent ...	£427	0	0
Depreciation on £2400 at 5 per cent ...	120	0	0
Depreciation on £760 at 6 per cent ...	46	0	0
	£593	0	0

550 VOLTS AT THE POWER HOUSE—500 VOLTS MINIMUM ON THE LINE

Without Battery — With Battery

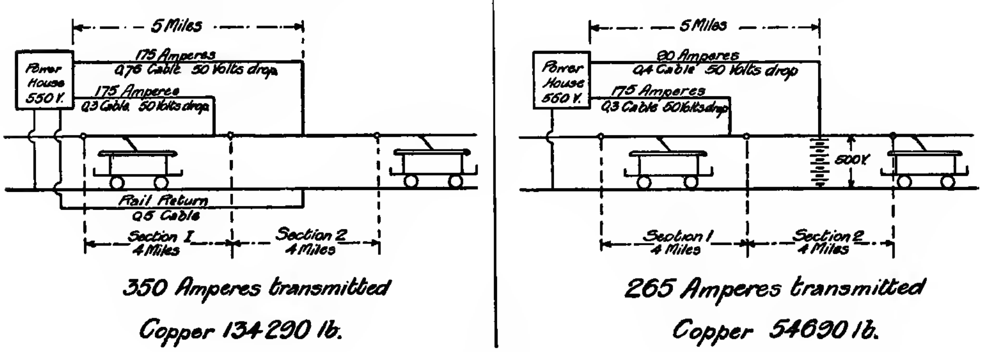


Fig. 5

It is thus claimed that in this particular instance a saving of £5757 in first cost and a reduction of £339 in annual charges are effected. [F. C.]

Accumulator, Active Material of, that portion of the plates in which the chemical conditions alter during each cycle of charge and discharge: in pasted plates the spongy lead or lead-salt which is applied to the grid, and in Planté plates the peroxide formed on the surface of the plates.

Accumulator, Bearers for, the horizontal supports for a stand for an accumulator or storage battery.

Accumulator, Booster set for. See Battery-booster set.

Accumulator, Cell-inspection Lamp for. See Lamp, Cell-inspection, for Accumulator.

Accumulator, Cell Tester for. See Tester, Cell, for Accumulator.

Accumulator, Cleaning Stick for, a thin piece of ebonite for passing down between the plates to dislodge any scale or any small piece of active material that may have bridged across.

Accumulator, Deterioration of.— Dependent very largely on the care and attention bestowed on the operation of the accumulator, on the number of charges and discharges per annum, and on the attendant conditions. May be anything from 5 per cent per annum on the first cost of a large cell to 10 per cent or 15 per cent for a small one. Manufacturers will quote maintenance rates.

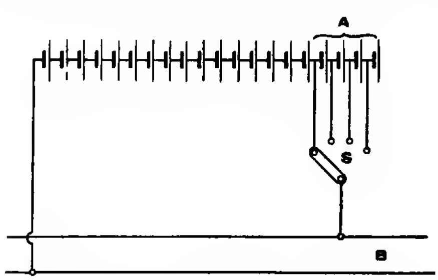
Accumulator, Drying off, the process of removing the electrolyte from the accumulator, or the plates from the electrolyte, when there is a likelihood of the accumulator not being used for a considerable time. It is chiefly applicable to accumulators for electric launches or electric vehicles, although the treatment is sometimes applied to accumulators for lighting. The details to be observed vary according to the type of accumulator to be dried off, and should not be undertaken without expert advice.

Accumulator, Efficiencies of.—ENERGY EFFICIENCY.—About 75 per cent to 80 per cent of the total electrical energy put into an accumulator can, under customary working conditions, be taken out again as electrical energy. The efficiency varies, however, according to the rates at which the accumulator is worked, and according to a considerable number of other circumstances. One of the causes of the loss in efficiency is the difference in voltage necessary to charge and that obtainable on discharge. The charging voltage may exceed 2·6 and the discharging voltage may be less than 2·0. This is also termed *real efficiency*.

AMPERE-HOUR EFFICIENCY, the ratio of output to input (discharge to charge) in amp hr. The amp hr efficiency will vary somewhat according to the rate at which the battery is discharged. It may be taken as about 90 per cent. The amp hr efficiency is sometimes termed *current efficiency*. [F. C.]

Accumulator, Electrostatic. See CONDENSER, ELECTRIC.

Accumulator, End Cells of, those cells shown at A in the diagram, which can be



A, End Cells. B, Discharge Main. S, Switch

introduced into or cut out of the circuit at such times as the condition of the main body of the accumulator requires that more or less cells should be in circuit to maintain constant voltage.

Accumulator, Exhausted Cell of, a cell in which the voltage across its terminals is insufficient to enable it to give any effective discharge.

Accumulator, First Charge of, a special prolonged charge necessary when an accumulator is first installed, in order to bring the plates into the required condition for successful operation.

Accumulator, Furring in. See TREEING.

Accumulator, Grid of, a lead casting (usually containing a small percentage of antimony), so designed as to hold the active material in place.

['*Grid*, in an accumulator. The framework supporting the active material.'—I. E. C.]

Accumulator, Group Charging of an, an arrangement whereby the total charging current is divided among two or more groups: a method not to be recommended, and permissible only where means are provided for ensuring that the rate of charge in each group can be independently regulated.

Accumulator, Hangers for, sheets of glass for supporting the plates at the desired height in the electrolyte.

Accumulator, Hydraulic.—Where the load factor of the demand for electrical power is low, the main source of supply may nevertheless be laid out with a capacity not greatly in excess of the *average* load, provided some means are present permitting of storing up enough energy to handle the peak loads. Thus the Victoria Falls Power Company, in a prospectus issued in 1906, described its then plan of employing a system of hydraulic accumulation of energy at the distributing end of its proposed 700-mile transmission line. In the words of the prospectus, this was 'in order to make profitable use of that considerable proportion (estimated at not less than one-quarter) of the transmitted power, which, owing to the intermittent character of the daily demand, would otherwise be entirely wasted'. The proposal was endorsed by R. D. Mershon and by Arthur Wright, consulting engineers to the Company. Unless natural formations are favourable to providing for hydraulic accumulation, the capital costs are usually enormous, and may more than offset any savings effected. In the Victoria Falls Company's proposition, the superfluous available electrical energy at times of light loads was to be absorbed in pumps driven by electric motors. These pumps were to lift water to the accumulator. During peak loads, the potential energy of the water was to be converted into electrical energy by turbo-generators.

Accumulator, Insulator Stand for. See INSULATOR STAND FOR ACCUMULATOR.

Accumulator, Milking. See MILKING.

Accumulator, Milking Cells of. See MILKING CELLS OF ACCUMULATOR.

Accumulator, Milking Clips for. See MILKING CLIPS FOR ACCUMULATOR.

Accumulator, Multiple-connected. See ACCUMULATORS IN PARALLEL.

Accumulator, Topping-up an, the process of adding to the electrolyte to maintain the depth of it over the tops of the plates, at the requisite level. It is preferable to use only distilled water for the purpose.

Accumulator Acid.—It is essential that the sulphuric acid for accumulators should be of the highest purity, and it should preferably be obtained direct from the makers of the cells with which it is to be used. It is usually sent already suitably diluted for putting into the cells. For export, however, it is shipped concentrated, with a sp gr of 1·84. See ACID, IMPURITIES IN.

Accumulator Car, a vehicle propelled by electrical power derived from accumulators carried on the car. The term is usually restricted to a vehicle adapted to run on rails. See also ELECTROMOBILE.

Accumulator Inspection Lamp. See LAMP, CELL INSPECTION, FOR ACCUMULATOR.

Accumulator Insulator. See INSULATORS.

Accumulator Lug, Hand of.—If the lug is at the left-hand end of the crossbar when the bar is between the observer and the plates, it is said to be a left-hand lug; if at the right end when the bar is between the observer and the plates, a right-hand lug.

Accumulator Plates.—The brown plates in a storage battery are called the positive plates, or, briefly, the positives; the grey are called the negative plates, or, briefly, the negatives. The tendency of the positive plates is to expand, and they are therefore designed with more mechanical strength than the negative plates, in which the tendency of the active material is rather to contract. In the smaller sizes, plates of the same polarity in each containing cell are joined to a connecting bar provided with a lead lug for coupling to a similar lug in the adjacent cell, but in the larger sizes the plates are of lead burned to a lead channel bar at right angles to the plates themselves. The various makes of plates on the market differ a good deal in design, but the chemical action in all types of lead cells is practically the same.

PASTED ACCUMULATOR PLATE, a type of accumulator plate in which the active material is applied to the support or grid in the form of a paste. It also includes those types in which the grid is cast round the active material.

POSITIVE PLATE, the brown-coloured plates in an accumulator cell. These are coupled to the positive terminal of the generator during charge.

FORMING POSITIVE PLATES, the process by which (1), in Planté type plates, the surface of the pure lead which is exposed to the electrolyte is caused to become coated with peroxide; and (2) by which, in pasted type plates, the active material is caused to become peroxidised. The means adopted vary.

NEGATIVE PLATE, the light-grey or slate-coloured plates in an accumulator cell. These are coupled to the negative pole of the generator during charge.

REDUCING NEGATIVE PLATES, the process by which the active material in the negative plates is reduced to spongy lead.

AMPERE HOURS PER KILOGRAM OF PLATE, the proportion which the weight, in kg, of the plate of an accumulator bears to the capacity in amp hr that can be obtained from it. Chiefly of interest in the case of traction accumulators. In comparing this value for various types of accumulator, the results should be reduced to some reference value, in volts, of the electrical pressure which the accumulator is to provide.

BUCKLING OF ACCUMULATOR PLATES.—This may be brought about by short circuiting, discharging at excessive rates, or by allowing the plates to become sulphated. This causes distortion of the plates, generally the positives. To counteract buckling, a small percentage of antimony is, in some types, mixed with the lead of which the grids are cast; in others, vertical or diagonal ribs are cast in the plate to increase its mechanical strength. Proper supervision of the operation of the accumulator is, however, essential to the avoidance of buckling, no matter what constructional provisions may have been made to this end.

['*Buckling of Accumulator Plates*, the distortion caused by uneven expansion.'—I. E. C.]

DISINTEGRATION OF ACCUMULATOR PLATES.—The depreciation of the positive (brown) plates is usually more rapid than that of the negative (grey) plates, since the active material becomes worn away and falls to the bottom of the containing vessel. The negative plates do not lose their active material to the same extent, but it is liable to contract, and may eventually fall away from the supporting grid. Ample space should therefore be provided underneath the plates for the accumulation of deposit.

REVERSAL OF ACCUMULATOR PLATES.—This may be brought about through over-discharging the accumulator, or through charging it in the wrong direction. The remedy is to avoid discharging beyond a safe limit, and to recharge for a period sufficient to bring the plates fully up to their normal condition.

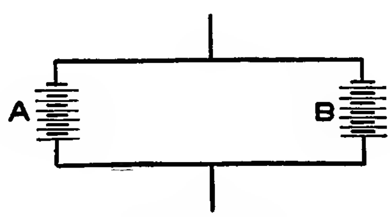
ENVELOPES FOR ACCUMULATOR PLATES, pockets of some acid-resisting material in which it was formerly sometimes the practice to place the positive plates in order to prevent any loose active material from bridging across to the negative plates. This method is now rarely employed.

See also ACCUMULATOR, LEAD. [F. C.]

Accumulator Switch. See SWITCH, ACCUMULATOR.

Accumulator Switchboard. See SWITCHBOARD, ACCUMULATOR.

Accumulators in Parallel.—The practice of connecting cells in parallel is not



Accumulators in Parallel

to be recommended, owing to the difficulty of preventing unevenness in working, more especially if new cells are paralleled with older ones. The advantage to be gained is that a larger amp hr capacity or an increased discharge rate is thereby secured with cells which, when connected in series, are capable of neither; but as a general practice it is to be deprecated.

If A and B are each capable of giving 100 amp for one hr, then, when arranged in parallel, 200 amp for one hr could be obtained, although at but half the voltage.

Acetate Wire. See WIRE, MAGNET.

Acetone. See ARTIFICIAL SOLVENTS.

Acheson Electric Furnace. See FURNACE, ELECTRIC.

Acid, Impurities in.—Sulphuric acid for use with accumulators should be of the highest purity and free from copper, platinum, iron, chlorine, arsenic, nitrogen acids, hydrochloric acid, and organic matter. A grade sometimes called 'commercially pure' acid is unsuitable for accumulators. See ACCUMULATOR ACID.

Acidometer. See HYDROMETER.

Acoustic Synchroniser. See SYNCHRONISER.

Actinic Carbons. See CARBONS.

Actinic Photometer. See PHOTOMETER, ACTINIC.

Actinic Rays. See LIGHT, ULTRA-VIOLET.

Actinometer. See PHOTOMETER, ACTINIC.

Active Coil, in a dynamo electric machine, a coil cutting lines of magnetic force, and therefore contributing to the emf of the circuit.

Active Conductor. See CONDUCTOR.

Active Material of Accumulator. See ACCUMULATOR, ACTIVE MATERIAL OF.

Active Polar Surface of Magnet. See POLAR FACE.

Active Wire, wire composing or forming part of an active coil. The term is also employed to denote the portion or portions of a coil which cut through the magnetic flux, as distinguished from the portions which serve merely to connect the active wires together. See also ACTIVE COIL.

Acyclic. See UNIPOLAR.

Acyclic Generator. See GENERATORS.

Adapter.—(1) Metallic filament lamps of small cp have not yet been developed for high voltages. Hence it is frequently convenient to connect a number of them in series with one another. This has led to the development of fittings for this purpose. Such fittings are frequently termed *adapters*.

(2) A device to permit of connecting a portable electric fitting, such as a portable lamp, to an ordinary lampholder. The device often takes the form of a plug suitably arranged to fit into the holder, and also to connect to the flexible conductor leading to the portable fitting. (Ref. 'Electric Wiring', W. C. Clinton.)

(3) An abbreviation sometimes employed for adapter transformers and for adapter compensators (see TRANSFORMER, ADAPTER).

Adhesion, Coefficient of, the ratio of the adhesion to the load upon the driving wheels of a car or locomotive. It is conveniently expressed in kg per ton, and is identical in nature with the coefficient of friction.

Adhesion between Wheel and Rail, the frictional resistance to relative motion by sliding, between a wheel and the rail upon which it rolls, due to the pressure between the surfaces in contact. The adhesion is proportional to the total pressure thus exerted, and to the coefficient of friction, which depends upon the nature and condition of the surfaces. The adhesion attains its maximum value at the moment when sliding is about to take place but has not begun, and this is the value usually taken. The adhesion may conveniently be expressed in kg per ton weight of car or train, in other words, by the ratio of the tractive effort just before slipping takes place, to the weight of the train. See also ADHESION, COEFFICIENT OF.

Adhesion Torque. See MAXIMUM ADHESION TORQUE.

Adhesion Weight, that proportion of the total weight of a car or locomotive which rests upon the driving wheels. See also ADHESION BETWEEN WHEEL AND RAIL.

Adhesive Tape, tape impregnated with a tacky adhesive compound which remains plastic for a considerable time. When used for taping, overlapping turns adhere together and form a covering which, according to the quality of the tape and the compound, may be more or less waterproof.

Adit, the trade name of an impregnated papier mâché manufactured in several qualities. The manufacturers claim that it is light, tough, and can be moulded to exact measurements. (Ref. 'The Insulation of Electric Machines', chap. vi, Turner and Hobart.)

Adjustable Condenser. See CONDENSERS.

Adjustable Speed Motor. See MOTOR, ADJUSTABLE SPEED.

Adjustment of Brushes. See BRUSHES, ADJUSTMENT OF.

Admission Pressure. See PRESSURE, ADMISSION.

Admittance, the reciprocal of impedance (which see), being the ratio of the rms current to the rms voltage in an apparatus carrying ac and in which no emf is supplied from outside. It is compounded of two elements, conductance and susceptance, proportional respectively to the component emf in phase and in quadrature with the current. If c be the conductance, s the susceptance, and y the admittance, then—

$$y = \sqrt{c^2 + s^2}.$$

The components of an admittance, made up of a number of admittances in parallel, are the sums of the corresponding components of the several admittances.

The unit of admittance is the mho (which see). See CONDUCTANCE and SUSCEPTANCE.

Aegma, a trade name for a metallic filament lamp placed on the market by the Allgemeine Elektricitäts-Gesellschaft. A E G are the initials of the firm, M A are the initial letters of Metallische Ader, the German for metallic vein. The lamp is a form of tungsten lamp.

Aerial, Tuning of, rendering the natural electrical vibration of the aerial conductor equal in frequency to that of the primary oscillating circuit. An ammeter (hot-wire) is put in the aerial, and the inductance, or capacity of the latter, is varied until a maximum reading is obtained, which indicates that revibration or resonance is taking place, *i.e.* that the aerial is 'in tune' with the main circuit. This is the working condition in tuned or syntonic wireless systems.

Aerial, Water Jet, in Wireless Telegraphy.—It has been proposed that a vertical jet of water might be used as an elevated conductor. Since, at the top, the jet breaks into drops, which become separated by considerable distances during their fall, the jet is practically a single vertical conductor and may be used as such.

Aerial Cable. See CABLE, AERIAL.

Aerial Conductor. See CABLE, AERIAL.

Aerial Transmitter. See TRANSMITTERS.

Aerial Wire. See CABLE, AERIAL.

Aetna Material, a hard stone-like composition often used in the manufacture of strain insulators. It has high compressive strength, and will withstand considerable heat and severe climatic conditions without disintegration. A test on an Aetna strain insulator gave the following results:—

Puncture pressure, 11,000 volts.
Insulation resistance, 20,000 megohms.
Tensile strength, 2·5 tons.

Ag, the chemical symbol for *silver* (which see).

Ageing, a term denoting the change in magnetic properties which takes place in the iron cores of transformers and other alternating apparatus. This change is usually manifested by an increase of hysteresis loss and a decrease of permeability. The effect was originally called *magnetic fatigue*, and was ascribed to the repeated magnetic reversals to which the iron was subjected. Later investigation showed it to be usually associated with heating, and entirely independent of the magnetic conditions. It is highly probable that it is an effect which occurs, although far more slowly, even at ordinary temperatures. Iron which is low in carbon, is especially subject to ageing; but the modern steels of which transformer cores are composed, are usually free from this drawback, and will usually not be subject to more than a few per cent increase of core loss after years of use.

Ageing of Filaments. See FILAMENT.

Ageing of Incandescent Lamps. See LAMP, INCANDESCENT ELECTRIC.

Ageing of Permanent Magnets. See PERMANENT MAGNET.

Ageing of Resistance Coils.—In accurate resistances (especially those of manganin, which see) it is found essential to subject the finished resistance to a careful annealing process, if it is desired to avoid alteration in value with time. A suitable treatment for bare resistances is to keep them heated for twenty-four hours at about 250° C. For silk-covered wire the temperature should not go beyond 100° C. unless the coils are immersed in oil, and the temperature should be maintained for a proportionally longer time.

Air, Dielectric Strength of. See DIELECTRIC STRENGTH.

Air Blast.—Electrical apparatus is frequently so arranged as to be cooled by means of a forced draught of air. Such apparatus is said to be of the air-blast type. Thus an air-blast transformer is a transformer provided with ventilating ducts through which air is forced by a suitable blower (see also AIR-COOLED; PIPE VENTILATED). In earlier days, the sparking of commutators was decreased in certain types of dynamos by arranging an air blast at the points where the brushes bear on the commutator. Air-blast apparatus constitutes part of the equipment of all well-managed electricity-supply undertakings. The apparatus is employed for blowing out the dust from the machinery in the station.

Air Brake. See BRAKES.

Air-break Switch. See SWITCH, AIR-BREAK.

Air Calorimetric Method of Testing Electric Generators. See TESTING ELECTRIC GENERATORS BY AIR CALORIMETRY.

Air Compressor, in electric traction, a small air pump carried on a car or locomotive, and driven by an electric motor or from one of the axles, for the purpose of supplying compressed air to work the air brakes, pneumatic contactors, &c. A steel tank is usually provided for storage of the compressed air, and the motor is automatically controlled, so that it stops directly the pressure attains its normal value. Air compressors are also used in workshops to operate pneumatic hoists and tools, and in dynamo rooms to blow dust out of the electrical apparatus.

Air Condenser, a condenser in which the dielectric is air. See also CONDENSER, ELECTRIC.

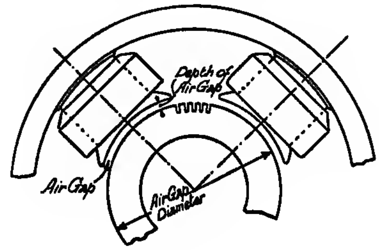
Air-cooled, a term applied to various kinds of electrical apparatus, but usually to transformers of the type in which the active material is not immersed in oil, reliance being placed on the maintenance of a suitably low temperature by the natural emission of heat from the external surface. By some engineers, however, the term *air-cooled* has been applied to apparatus in which air is *forced* through ducts. But this latter type is preferably designated the air-blast (which see) type. See also PIPE VENTILATED.

Air-drying Core-plate Varnishes. See CORE-PLATE VARNISHES.

Air-drying Varnishes. See INSULATING VARNISHES; also CORE-PLATE VARNISHES.

Air Ducts. See DUCTS, VENTILATING OR AIR.

Air Dynamometer for Testing Electric Motors. See DYNAMOMETER, AIR, FOR TESTING ELECTRIC MOTORS.



Air Gap

Air Gap, that part of any magnetic circuit where the lines of magnetic force have to pass from iron to iron in air. More particularly, in dynamo electric machines, the space between the armature and magnets, or between the rotor and stator (see fig.).

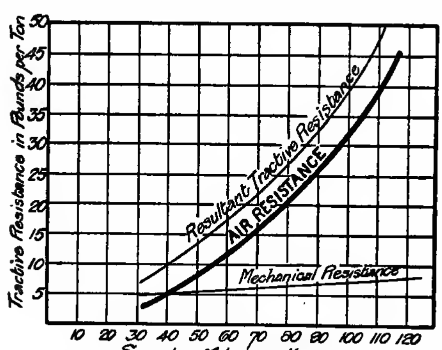
Air-gap Depth, in dynamo electric machines, the distance between the iron of armature and magnets, or between the iron of rotor and stator, measured along a radius. The air-gap depth in mm is frequently denoted by Δ (see fig. illustrating AIR GAP). See also CLEARANCE.

Air-gap Diameter.—Designers of dynamo electric machinery frequently employ D, the air-gap diameter, in cm, in establishing comparisons between alternative designs and in various steps in their calculations. Where exactness is essential, the diameter to the periphery of the armature, no matter whether this be the rotor or the stator, is usually taken as the air-gap diameter (see fig. illustrating AIR GAP).

Air-gap Reluctance. See GAP RELUCTANCE.

Air Magnetic Circuit. See MAGNETIC CIRCUIT.

Air Resistance, in electric traction, the frictional resistance offered by the air to the



Curves of Air Resistance (and other Resistances) of 83 Ton Car

motion of a train or car. The air resistance, as may be seen from the curves in the fig., increases far more rapidly than the velocity of the train or car.

Air-space Cable. See CABLE, AIR-SPACE.

Air-type Switches. See SWITCHES, AIR-TYPE.

Ajax Insulating Varnishes, the trade name given to a line of baking and air-drying insulating varnishes designed to meet the varied requirements arising in practice. See also INSULATING VARNISHES.

Ajax Lightning Arresters. See LIGHTNING ARRESTERS.

Al, the chemical symbol for *aluminium* (which see).

Alabaster, a variety of gypsum. It is sometimes used for shades for electric lamps, on account of its diffusing property. Its absorption power is, however, only some 20 per cent, whereas with modern metallic filament lamps it is gradually coming to be considered good practice to employ shades of higher absorption power.

Alarm, Electric, an electrical device which indicates—by ringing a bell, lighting a lamp, or otherwise—the occurrence of some movement or change, such as the opening of a door, the reduction of water level in a boiler to the limit of safety, or a rise in temperature (automatic fire-alarm). The change to be indicated is arranged to make or break a circuit containing a battery and the bell or other indicator.

Alcohols.—Alcohols are widely employed in the electrical industry as components of insulating varnishes. The alcohol solvents comprise:—

1. Methyl alcohol (wood naphtha).
2. Ethyl alcohol.
3. Amyl alcohol.
4. Methylated spirit.

These solvents are employed only for spirit varnishes.

METHYL ALCOHOL.—This is a homologue of ethyl alcohol, and has the composition indicated by the formula CH_3OH. When pure, it is a colourless volatile liquid, possessing great solvent powers. See also 'Wood Naphtha' under NAPHTHA.

ETHYL ALCOHOL.—When pure this is known as *absolute alcohol*, and is an extremely volatile liquid with a composition indicated by the formula C_2H_5OH. It is never employed alone for thinning spirit varnishes, on account of the high rate of duty levied by the Excise authorities. The hard copals are insoluble in it, and it readily absorbs moisture from the atmosphere. It is the chief constituent of methylated spirit.

AMYL ALCOHOL.—This occurs as a by-product in the manufacture of ethyl alcohol, under the term *fusel oil.* Pure amyl alcohol is isobutyl carbinol, and has solvent properties similar to ethyl alcohol, but does not evaporate so rapidly. It is used for thinning lacquers for metal work. Fusel oil contains principally amyl alcohol and one or more of its isomerides.

METHYLATED SPIRIT.—This consists essentially of a mixture of ethyl and methyl alcohols, usually in the proportion of nine parts of the former to one of the latter. The use of wood naphtha for methyl alcohol renders the mixture unfit to drink. But owing to improvements in the manufacture of wood naphtha, the nauseous taste is nowadays absent. Consequently the Excise authorities require the addition of a small percentage of petroleum oil. The use of the original spirit is, however, for manufacturing purposes, still allowed by special permit.

Methylated spirit is a very volatile solvent, and evaporates rapidly at all ordinary temperatures. Many resins are soluble in it, and its use as a thinner allows the varnish to rapidly air-dry. It readily absorbs moisture from the atmosphere, and generally has an acid reaction, due to the presence of small quantities of acetic acid and aldehyde. This renders it unsuitable as a solvent for insulating varnishes, but it is extensively used as a thinner for mica-sticking and spirit varnishes. [H. D. S.]

Alive.—The term *alive* is applied to any exposed metal carrying an emf. As instances of such exposed metal, may be mentioned the metal work of a switch, or the terminals and brush gear of a dynamo.

LIVE WIRE, a wire carrying an emf, more particularly when the wire is uninsulated, such as the overhead wire of an electric tramway.

Alkali Accumulator. See ACCUMULATOR.

'All Day' Efficiency. See EFFICIENCY.

Alloyed Iron. See STEEL.

Alloyed Steel. See STEEL.

Alloys, High-resistance. See HIGH-RESISTANCE ALLOYS.

Alternate Current. See ALTERNATING and ALTERNATING CURRENT.

Alternating, a word used with a large number of electrical and magnetic quantities, denoting that their magnitudes continuously vary, passing repeatedly through a definite cycle of values in a definite period of time, and are such that a half period after any instant, finds them unchanged in value but reversed in direction as compared with the conditions at the instant. This may be represented by a curve in which the abscissæ represent time, and the ordinates represent the instantaneous values of the alternating quantity.

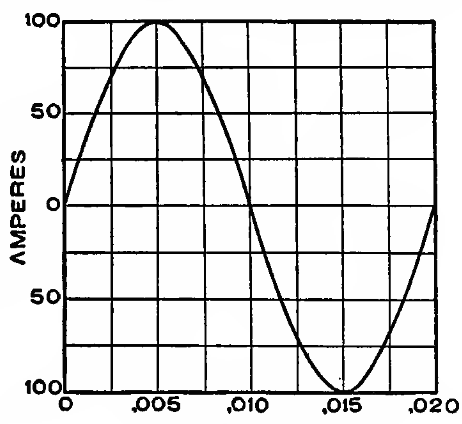
Alternating Current (preferable abbreviation ac).—An ac is represented diagrammatically in the illustration, in which ordinates represent current in amperes, and abscissæ represent time in seconds.

Starting from zero, the current rises to a maximum, falls to zero, rises to a maximum in the opposite direction, and again falls to zero, this succession of changes being repeated continuously, usually many times per second.

['*Alternating Current*, an electric current which alternately reverses its direction around a circuit in a periodic manner. The time occupied by each pair of half-waves is called a *period*.'—I. E. C.]

[Paragraph 5 of the 1907 Standardisation Rules of the A.I.E.E. reads as follows: 'An ac is a current which, when plotted, consists of half-waves of equal area in successively opposite directions from the zero line'.]

CYCLE OF ALTERNATION.—The current starts from zero, rises in this example to 100 amp, and falls back to zero in 0·01 sec.



Alternating Current

This was formerly known in America as one alternation.

FREQUENCY OF ALTERNATION.—The number of alternations per second (in the present case, 100) used, in America, to be termed the *frequency of alternation.* This term is seldom if ever used in this country, and its use has also been almost completely abandoned in America.

Referring again to the diagram, it will be noted that at the expiration of 0·01 sec from the start, the current reverses its direction. It then rises to an intensity of 100 amp, and at the expiration of

0·02 sec from the commencement it has again fallen to zero, and is ready to repeat the process shown in the illustration. It has thus gone through a complete *cycle* or period.

PERIODICITY.—The number of these complete cycles per second is termed the *periodicity* or *frequency*. In this case the periodicity is $\left(\frac{1 \cdot 00}{0 \cdot 02} = \right)$ 50 cycles per second.

ALTERNATING EMF.—To produce an ac an alternating emf is necessary, and this is provided by a machine having no commutator. See ALTERNATOR. These ac and emf are occasionally known as *periodic currents* and emf. The terms *alternating pressure* and *alternating voltage* are often used as synonymous with alternating emf.

MONOPHASE OR SINGLE-PHASE CURRENT.—The illustration already described represents a monophase or s ph current. This is generated by an alternator having a single winding on its armature. Two mains, a lead and return, are used, as in cc work, to conduct the current.

TWO-PHASE CURRENT.—If two windings are placed on the alternator armature at 90 magnetic degrees, a single-phase current will be generated in each of the windings, the current in one winding being at its maximum value when the other is at zero. In this case four transmission conductors are generally used, two for each separate circuit, and the motors to which the current is led have a double winding corresponding to that on the alternator armature.

THREE-PHASE CURRENT.—If three separate windings be placed on the alternator armature at 60 magnetic degrees from one another, the current in each will attain its maximum at a point one-third of a cycle distant from the other two. For the conduction of three-phase current, it is not customary to use three separate pairs of conductors. Instead, three ends (one of each of the three armature windings) are brought together to a common connection, and only three conductors are used to transmit the current. See also WINDING, ALTERNATING-CURRENT ARMATURE; ALTERNATOR; ALTERNATING-CURRENT SYSTEM; ALTERNATING-CURRENT TRANSMISSION.

Alternating-current Ammeter. See AMMETER.

Alternating-current Armature Windings. See WINDINGS, ALTERNATING-CURRENT ARMATURE.

Alternating-current Balancer. See BALANCER, ALTERNATING-CURRENT.

Alternating-current Booster. See BOOSTER.

Alternating-current Compensator. See COMPENSATOR, THREE-WIRE ALTERNATING-CURRENT.

Alternating-current Electricity. See ELECTRICITY, ALTERNATING.

Alternating-current Electromagnet. See ELECTROMAGNET FOR ALTERNATING CURRENTS.

Alternating-current Generator. See ALTERNATOR.

Alternating-current Meter. See METERS, ALTERNATING-CURRENT.

Alternating-current Motor. See MOTOR, ALTERNATING-CURRENT.

Alternating-current Rectifier. See RECTIFIER.

Alternating-current Single-phase System. See GENERATING SYSTEMS; ALTERNATING CURRENT; ALTERNATING-CURRENT SYSTEM.

Alternating-current Switchboard Integrating Meters. See METERS, SWITCHBOARD INTEGRATING.

Alternating-current System, an electrical system, the current in which changes rapidly in direction, increasing from zero to a maximum in one direction, then decreasing to zero, then increasing to a maximum in the opposite direction, and again decreasing to zero, and repeating this cycle indefinitely. This is the nature of the current (as also of the emf producing it), which is generated when a conductor is revolved in front of two or more magnetic poles alternately north and south. Such a generator is called an *alternator*. The ac is the natural one produced by the machine, and to obtain a cc an artificial device, the commutator, has to be added. It is therefore not without reason that alternating currents should be largely employed, on account of the simplicity of the machinery required for their generation, and similarly for their conversion, by means of motors, back into energy of rotation.

If, in addition to the first revolving conductor, or conductors, others are added, two-thirds of the polar pitch apart, and led to three separate terminals, three-phase current is generated, while if the added conductors are half the polar pitch apart, the current generated is two-phase. Two- and three-phase systems have certain advantages over single-phase systems. One of these advantages is that, for a given size of generator, transformer, or motor, a greater output can be obtained in the two former cases. A further advantage is that induction motors start readily on polyphase circuits (that is, two- or three-phase circuits), while in the case of single-phase motors, special devices have to be employed to achieve this end. These devices rarely give complete satisfaction. Further, the three-phase system can show a reduction in the amount of copper required for the transmission of a given amount of power with a given maximum pressure between conductors. The relative figures for the amount of transmission copper required, are as follows. (Ref. Steinmetz, 'Alternating Current Phenomena'.)

Single-phase system	(2 wires)	100
Three-phase „	(3 wires)	75
Two-phase „	(4 wires)	100

These comparative figures are based on an equal pressure between any two wires.

Single-phase currents were, and still are, used to a large extent for arc and incandescent lighting through the intermediary of transformers, and, more recently, s ph working has come to the front in connection with the use of series or repulsion s ph motors for railway service.

The number of complete periods or cycles per second is called the *periodicity* or *frequency* of the circuit. This is, of course, half the number of alternations per second. Some years ago, frequencies of 100 cycles per second and more, were common, but now 40, 50, or 60 cycles per second are generally adopted for power and lighting purposes. 25 cycles per second are often selected where rotary converters are to be installed. For s ph railway work, periodicities as low as 15 are met with. See also ALTERNATING CURRENT; POLYPHASE SYSTEM.

Alternating - current Tests, Liquid Resistances for. See 'Liquid Rheostat' under RHEOSTATS OR RESISTANCES.

Alternating - current Three - phase System. See GENERATING SYSTEMS; ALTERNATING CURRENT; ALTERNATING-CURRENT SYSTEM.

Alternating - current Transmission, the transmission of energy from one place to another by means of ac. The term is generally confined to transmission over a considerable distance; and since a high voltage is essential to a long-distance transmission, owing to the necessity for reducing the area of the conductors as much as possible, and since the commutator limits the voltage of cc machines, ac are generally employed for such transmissions: the only exceptions are a few plants operated on the Thury Series Continuous - current System. The ac employed are generally three-phase, for several reasons. Thus three-phase motors are self - starting. Moreover, for a given maximum potential difference between conductors, the weight of copper required in the line is less than with any other form of ac. See also ALTERNATING - CURRENT SYSTEM.

As instances of the distances to which ac transmissions are carried, the following may be noted:—

	Kw.	Volts.	Miles.	Frequency.
California Gas & Electric Co.	50,000	60,000	232	60
Washington Water Power Co.	9,000	60,000	110	60
Los Angeles Edison Co.	20,000	60,000	139	50
Hercules Power Co., Utah	2,000	40,000	150	60
Electrical Development Co., Niagara ...	88,000	60,000	90	25

See also ENERGY, ELECTRIC TRANSMISSION OF; CONDUCTORS, OVERHEAD; 'Wooden Line Poles' under LINE POLES; TRANSMISSION LINES, STEEL TOWER. (Ref. 'Electric Power Transmission', Louis Bell; 'The Electrical Transmission of Energy', Abbott; 'Modern Electric Practice', vol. iii; 'Long-distance Electric Power Transmission', Hutchinson.)

Alternating - current Two - phase System. See GENERATING SYSTEMS; ALTERNATING-CURRENT SYSTEM.

Alternating-current Wattmeter. See WATTMETER.

Alternating Electricity. See ELECTRICITY, ALTERNATING.

Alternating emf. See ALTERNATING CURRENT.

Alternating Field. See FIELD, ALTERNATING.

Alternating Flux. See FLUX, ALTERNATING.

Alternating Pressure. See under ALTERNATING CURRENT.

Alternating Voltage. See under ALTERNATING CURRENT.

Alternator, a dynamo electric machine used for converting energy in the form of mechanical power into energy in the form of alternating electric currents.

['*Alternator,* a machine for generating ac. The exciting current is generally supplied by a separate machine called an *exciter.* (The word *dynamo* should be reserved for a cc generator.)'.—I. E. C.]

A SINGLE-PHASE ALTERNATOR or SINGLE-PHASE GENERATOR is a machine generating a single ac.

A TWO-PHASE ALTERNATOR is one which produces two ac with a phase difference of 90°.

A THREE-PHASE ALTERNATOR is a machine producing three alternating currents with a phase difference of 120°. The two types last mentioned are also called *polyphase alternators* or *polyphase generators.* Alternators are usually separately excited, the current circulating in the field-magnet winding being derived from an independent source of cc; but they can be made self-exciting (see 'Heyland Polyphase Generator' under GENERATORS.

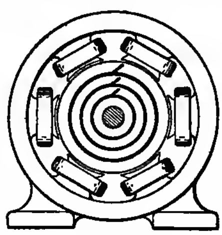


Fig. 1.—Revolving Armature Type of Alternator

REVOLVING ARMATURE TYPE OF ALTERNATOR.—In this type of alternator the armature revolves and the field-magnet system is stationary. This type has been for some years discarded (for all except a very small range of ratings), principally on account of the difficulty of collecting currents at high pressures from a rotating member. It is illustrated diagrammatically in fig. 1.

MONOTOOTH ALTERNATOR, a designation applied to a machine of the revolving-armature type which was put on the market some years ago. All the armature conductors under one pole were collected in one large slot. A distinctive feature was that the two slots holding the two sides of a core were parallel and not radial (see fig. 2), so that a formed or insulated coil could be laid directly into the armature slots. The construction is now obsolete.

REVOLVING-FIELD TYPE OF ALTERNATOR.—In this type, now almost universally adopted, the armature is stationary and the magnet system revolves, the exciting current being introduced, at a pressure usually not exceeding 400 volts, by means of a pair of slip rings (see fig. 3).

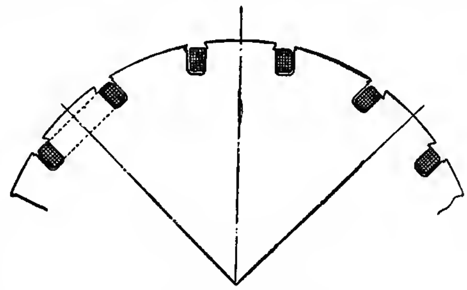


Fig. 2.—Monotooth Alternator

[On p. 8 of the Engineering Standards Committee's 'Report on British Standards for Electrical Machinery' (No. 36, August, 1907) it is stated that 'For exciting the field magnets the standard pressures shall be 65, 110, or 220 volts'.]

The construction allows the stator leads (*i.e.* the leads from the armature winding), often at h pr (2000 to 20,000 volts), to be carried straight away from the machine without the intervention of the sliding or revolving contacts which were required in the earlier type of construction with a revolving armature (which see).

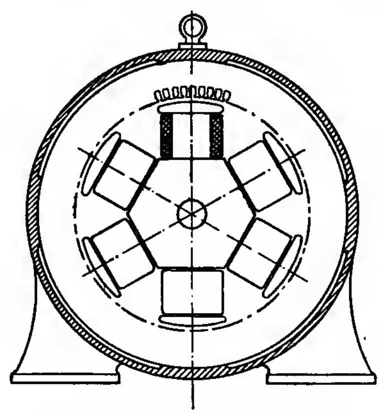


Fig. 3.—Revolving-field Type of Alternator

FLYWHEEL TYPE OF ALTERNATOR.—This is not strictly a type, but a method of construction. In slow-speed engine-driven sets, especially gas-engine-driven sets, the turning effort is not uniform throughout the revolution, so that appreciable fluctuations in speed occur which prevent good parallel running. To minimise this effect, very large flywheels are used See VARIATION IN ALTERNATORS; PULSATION IN ALTERNATORS; ALTERNATORS, PARALLEL RUNNING OF. The flywheel often serves as the yoke of the magnet system, thus dispensing with a separate magnet wheel, the poles being bolted to the rim. The rotor of a flywheel alternator is shown in fig. 4.

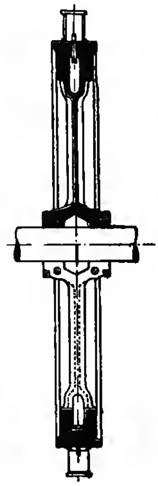


Fig. 4.—Rotor of Flywheel Alternator

OVERHUNG TYPE OF ALTERNATOR.—This is a modification of the revolving-field type of alternator. Its distinctive feature is that the revolving-magnet system is made exterior to the stator. This is with a view to obtaining a maximum of flywheel effect for a given diameter of stator. Further, the amount of active iron is reduced to a minimum. The construction is not often used, because of the mechanical difficulties of mounting and driving a heavy magnet wheel from one end. The ventilation of these machines has to be carefully considered, for whereas in the ordinary revolving-field type of machine the stator windings and core are cooled by the centrifugal action of air propelled radially from the rotor, no such natural means are available in the overhung type. Fig. 5 is an example of a machine of this type.

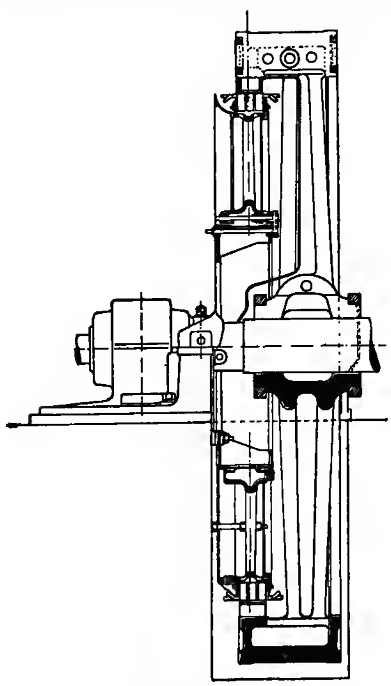


Fig. 5.—Overhung Type of Alternator

TRUNNION TYPE OF ALTERNATOR.—This is a type of mechanical construction adopted by Messrs. Brown, Boveri, & Co., of Zurich, for large slow-speed machines. The stator housing has no feet, but is supported on each side by flanged arms, radiating from a central hub which forms a trunnion bearing upon a bracket from the machine-bearing pedestal. The stator is prevented from revolving by set screws from a foundation plate, which, when slacked back, allow the armature to be revolved on its trunnion bearing for the inspection and repair of those parts which would otherwise be down in the machine pit, and hence difficult of access. A machine of this type is illustrated in fig. 6.

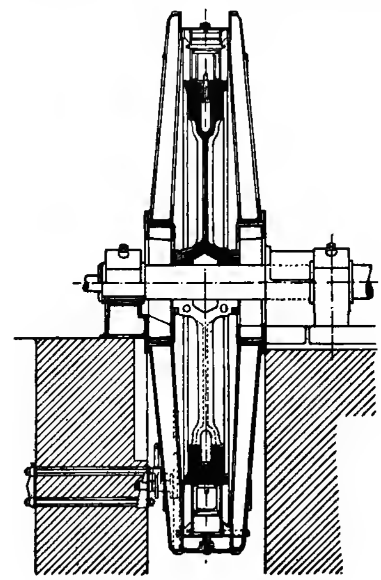


Fig. 6.—Trunnion Type of Alternator

UMBRELLA TYPE OF ALTERNATOR.—This is a revolving-field type machine, mounted vertically. Its peculiar name is derived from the circumstance that it has no top bearing, and in order that the centre of gravity of the whole revolving system, spider, rim, and magnets, may be on a line with the lower bearing, the arms of the spider form the corners of the sides of a pyramid, and the arrangement has the appearance of an umbrella. This type of machine is used mostly in connection with vertical water wheels. As typical alternators of this construction may be mentioned those installed at Niagara some sixteen years ago. The first machines were wound for 2200 volts, ran at a speed of 250 rpm, and had a rated capacity of 3750 kw

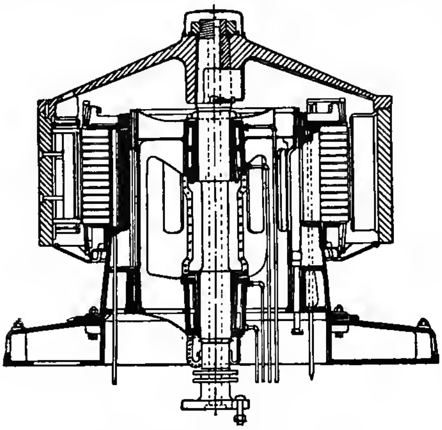


Fig. 7.—Umbrella Type of Alternator

each. The type was adopted in this instance under the advice of Professor George Forbes, and the machines were supplied by the Westinghouse Company. One of these machines is illustrated in fig. 7.

INDUCTOR TYPE OF ALTERNATOR.—In this type of alternator the rotating member forms the magnet polar system but carries

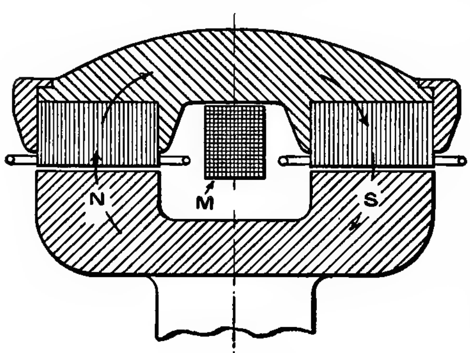


Fig. 8.—Inductor Type of Alternator

no windings. Fig. 8 shows diagrammatically this type of machine. The common magnetising coil, which runs right round the machine, creates a magnetic flux as indicated by the arrows. The polar projections N S on the rotating member, form the magnetic poles which induce emf in the two armatures, which may be connected up in series, in parallel, or in any other suitable manner. This type of machine is rarely made now, chiefly because only half as great a pressure is obtained by a flux of given amount, as would be obtained in the ordinary type of machine. It is also more expensive to build two armatures, to give the same power, than to build one armature. This type has still other grave defects, amongst which may be mentioned enormous magnetic leakage, heavy eddy-current losses, inferior heat emissivity, and bad regulation. The inductor type of alternator may be regarded as closely related to the homopolar type of construction. See also GENERATOR. [H. W. T.]

[In paragraph 9 of the 1907 Standardisation Rules of the A.I.E.E. an *Alternator* or *Alternating-current Generator* is defined as a machine which 'produces alternating current, either single phase or polyphase'. In paragraph 10 a *Polyphase Generator* is defined as a machine which 'produces currents differing symmetrically in phase; such as two-phase currents, in which the terminal voltages on the two circuits differ in phase by 90°; or three-phase currents, in which the terminal voltages on the three circuits differ in phase by 120°'.]

'*Alternator*, a machine for generating alternating current. The exciting current is generally supplied by a separate machine called an *exciter*. (The word *dynamo* should be reserved for a continuous-current generator.)'—I.E.C.]

Alternator, Compensated. See ALTERNATOR, COMPOUND-WOUND; 'Heyland Polyphase Generator' under GENERATOR.

Alternator, Compound-wound, an ac generator which, in addition to the usual separate excitation by cc, is provided with field-magnet windings traversed by a rectified current derived from and proportional to the current generated by the machine itself. The rectified current may be obtained either from the armature or part of the armature of the generator, or from a transformer connected in circuit with the armature; in either case a rectifying commutator, or equivalent device, is necessary. Another method is to cause the rectified current to act upon the field magnet of the cc exciter. The compounding may compensate for voltage drop or phase displacement, or for both. See 'Heyland Polyphase Generator' under GENERATOR. (Ref. 'Alternating Currents', by A. Hay, pp. 265–270.)

Alternator, Homopolar. See 'Homopolar Generator' under GENERATOR; also 'Inductor Type of Alternator' under ALTERNATOR.

Alternator, Incoming, an alternating current generator ready, or being brought to a state of readiness, for switching in parallel, or for synchronising with other ac machines. See SYNCHRONISING DYNAMO ELECTRIC MACHINES.

Alternator, Monocyclic, a single-phase generator provided with a supplementary winding in which is generated an emf in quadrature with the main emf. The armature is star-connected, and supplies power to motors on the three-phase system, while lamps are supplied on the single-phase system. This type of generator is practically obsolete. See MONOCYCLIC SYSTEM.

Alternator, Panchronous, a type of ac generator devised independently by Latour and by Heyland. The revolving field carries a commutator on which are arranged (for three-phase working) three equispaced sets of brushes per pair of poles, the three sets of brushes being in conducting connection with the three-phase supply either directly or through transformers. Such panchronous dynamos are self-exciting, and while the revolving field is preferably driven in the near neighbourhood of synchronism, as this is the condition corresponding to the best commutation, there is no occasion for the preservation of absolute synchronism.

Alternators, Parallel Running of, the state of two or more alternators driven by prime movers, the alternator terminals being connected together to a common set of conductors as bus bars, and the emf being adjusted to synchronise; the state of two or more alternators after being synchronised. See AMORTISSEUR; DAMPING.

Alternator, Pitch of. See 'Polar Pitch' under PITCH.

Alternator, Polyphase, an ac generator which gives out two or more currents differing in phase; usually either two-phase or three-phase. See also under ALTERNATOR.

Alternator, Pressure Regulation of an.—

[On p. 8 of the Engineering Standards Committee's 'Report on British Standards for Electrical Machinery' (No. 36, August, 1907) it is stated that 'The regulation of an alternator shall be expressed as the rise in pressure from full load to no load with constant speed and excitation. The "pressure rise" is defined as the difference in volts between full load and no load, stated as a percentage of the full load pressure.

'The pressure rise shall not exceed six per cent (6%) on a non-inductive load and twenty per cent (20%) on an inductive load having a power factor of 0·8. This pressure rise may be tested on a non-inductive or inductive load according to the requirements of the specification.']

This percentage by which the terminal pressure rises when the load is decreased from full load to no load without changing the speed or the field excitation, is generally termed the *inherent regulation,* and it should preferably be specified for full load at unity pf, and also for full load at a pf of 0·8. These two values may be termed respectively the *inherent regulation at unity power factor* and the *inherent regulation at a power factor of 0·8.* In connection with the pressure regulation of an alternator, it is often of importance to consider the *excitation regulation,* which may be defined as the percentage increase, above that for no load, required in the excitation of an alternator, in order that, at rated amperes output, the rated pressure may be maintained. Like the inherent regulation, the excitation regulation is a function of the pf, and hence the corresponding pf must always be stated. See also REGULATION; POTENTIAL REGULATION; EXCITATION. (Ref. chap. v of Hobart and Ellis's 'High Speed Dynamo Electric Machinery'.)

Alternator, Pulsation in. See PULSATION IN ALTERNATORS; VARIATION IN ALTERNATORS; ALTERNATORS, PARALLEL RUNNING OF.

Alternator, Self-exciting. See 'Heyland Polyphase Generator' under GENERATORS; ALTERNATOR, COMPOUND-WOUND; ALTERNATOR, PANCHRONOUS.

Alternator, Three-coil Armature Winding of. See WINDING, THREE-COIL ARMATURE, OF ALTERNATOR.

Alternator, Variation in. See VARIATION IN ALTERNATORS; PULSATION IN ALTERNATORS; ALTERNATORS, PARALLEL RUNNING OF.

Alternator Armature. See ARMATURE.

Alternator Voltage. See VOLTAGE, ALTERNATOR.

Aluminium (chemical symbol = Al).—Aluminium, on account of its low cost, its extreme lightness, and various other of its properties, is becoming a serious rival to copper as a conductor of electricity. Until recently the relatively high price of aluminium militated against its general adoption for electrical purposes; but now that improved methods of production have enabled the price to be brought down to a point at which, for equal conductivity, it shows a great saving over copper, there appears every likelihood of its supplanting the older metal for many purposes where lightness and ease of handling are considerations, apart from the saving in cost that can thereby be effected.

For electrical purposes, pure aluminium has a conductivity of about 60 per cent of that of electrolytic copper, so that to obtain the same conductivity as copper, the sectional area must be increased by about 66 per cent. This is equivalent to increasing the diameter by 29 per cent in the case of a round solid wire.

This extra 29 per cent in diameter somewhat increases the cost of the insulation in the case of underground cables. Consequently for small h pr cables, where the cost of the insulation is the chief factor governing the price of the cable, the copper cable will often be found cheaper, unless the price of copper be abnormally high. But for large l pr cables, of which enormous quantities are now employed in all large cities, there is undoubtedly a wide field for aluminium, since, apart from any saving in first cost, there is the lower cost of transport, and the greater ease of handling of the lighter cable, to be taken into consideration. For bus bars, connections between generators and switchboards, and many other cases where it has heretofore been customary to use bare copper strip, a great gain both in initial cost and in ease of handling, is now being attained by employing aluminium.

The following table, giving the physical properties of aluminium and copper, will be found of use in comparing the relative advantages of the two metals for any particular purpose:—

TABLE OF COMPARISONS BETWEEN COPPER AND ALUMINIUM AS USED FOR ELECTRICAL PURPOSES

	Copper.	Aluminium.
Symbol	Cu	Al
Atomic weight (pure)	63·2	27
Atomic volume (pure)	7·2	10·6
Melting-point (about)	1060° C.	625° C.
Specific gravity	8·9	2·7
Specific heat (water 1)	0·094	0·212
Thermal conductivity (Silver=100) ...	73·6	31·3
Coefficient of linear expansion	0·000017 per ° C.	0·000023 per ° C.
Tensile strength (roughly)	4,200 kg per sq cm	2,100 kg per sq cm
Modulus of elasticity	1,120,000 „ „	630,000 „ „
Electric conductivity (Silver=100) ...	97·50	58·5
Position in electrochemical series ...	24	10
Section for equal conductivity	1	1·66
Diameter „ „	1	1·29
Weight „ „	1	0·5

Taking the relative specific gravities of aluminium and copper wire as 2·7 and 8·9 respectively, and taking into account the increased section of the aluminium wire, it will be seen that to obtain the same conductivity per unit length as for copper, only half the weight of aluminium is required. From this it follows that if the price of aluminium per ton, is double that of copper, the two metals will cost the same on the basis of price for equal conductivity, and that any decrease in the price of aluminium below this figure, means so much saved on the bare conductor, by employing aluminium in place of copper. As the price of aluminium may often be less than 20 per cent higher than that of copper, it will be seen that the saving which may be effected by its use is enormous.

The tensile strength per unit area of aluminium is about half that of copper; but when the increased sectional area required to obtain the same conductivity, is taken into account, the effective tensile strength of an aluminium wire is about 75 per cent of that of the conductively equivalent copper wire. In the case of very small overhead wires, this lower tensile strength may in certain cases be a disadvantage; but for the usual sizes of conductors used for overhead power transmission, the lower tensile strength is more than compensated for by the lower weight, which also allows a lighter pole construction and an increased pole spacing to be employed, except in so far as the increased sag occurring with aluminium imposes a limitation. It is claimed that it has been found in actual practice that the oily

ALUMINIUM FEEDER CONNECTIONS BUTT-WELDED ON SITE

(By courtesy of the British Aluminium Company, Ltd.)

[To face p. 18.

nature of the surface of aluminium wire materially reduces the amount of snow and sleet that usually become attached to copper transmission lines, thus removing one of the chief causes of breakages of lines laid in exposed country.

For small overhead telegraph and telephone lines, pure aluminium is not suitable, owing to the lower tensile strength; and in this case an alloy of aluminium with a small percentage of copper has been used. This alloy has a tensile strength equal to that of copper, with about one-third the weight, and a conductivity of about 50 per cent of that of copper, the resistance of such lines being, as a rule, of but secondary importance.

Aluminium wires are very ductile, and can, without fracturing, be twisted one complete turn, in a length equal to their own diameter. The heating effect for an aluminium wire is less than for a copper wire of the same resistance and length, owing to the larger cooling surface exposed, so that not only will an aluminium wire remain cooler when carrying a given current, but it will also have a larger overload capacity from a heating point of view, than will a copper wire of equal resistance.

Pure aluminium is little acted upon by any of the common acids in a cold state, with the exception of hydrochloric acid, and its advocates claim that it withstands the action of sea water better than either copper or iron. Galvanic action is, however, at once set up between aluminium and any of the common metals in the presence of moisture, and for this reason copper or iron clamps should not be used for outdoor work unless the junction be taped over or otherwise protected from moisture. For indoor work, such as the connections between generators and switchboard, bus bars, &c., ordinary mechanical clamps may be used; but where these are exposed to the action of acid fumes or of impure air, as in the case of battery-room connections, the junctions should be covered with acid-resisting paint. Where these precautions are taken, less trouble is experienced with aluminium than with copper, for these purposes, since the metal itself is far less affected by acid fumes, while its extreme lightness makes it particularly suitable for this class of work.

No thoroughly satisfactory permanent solder has yet been discovered for aluminium, the chief difficulty being to get rid of the thin film of oxide that forms immediately on the surface of the metal when exposed to the atmosphere. However, the ease with which aluminium can be welded compensates to a large extent for the difficulties of soldering. The chief point to be borne in mind in making aluminium joints is to use only aluminium, the presence of any other metal tending to set up electrolytic action in the presence of moisture.

In jointing aluminium the usual practice has been to use a sleeve torsion (McIntyre) or other form of mechanical joint for overhead conductors and stranded cables, while for underground and other concealed conductors, a welded joint has been found most satisfactory. The usual method of making the weld, is to bring together the two ends to be joined and to clamp a cast-iron, cigar-shaped mould around the joint. Aluminium, previously melted over an ordinary portable fire, is poured into this mould. When the mould has been removed and the joint trimmed, it is found to be in every way equal to the rest of the conductor. Solid wires up to $\frac{3}{4}$ in. diameter, may be welded in the flame of an ordinary blowpipe, end pressure being applied at the moment of welding to drive out the film of oxide between the two surfaces of the joint. For welding more complicated sections, which do not lend themselves easily to either of these methods, the system known as the autogenous weld (see WELDING, AUTOGENOUS) may be employed. This consists in heating the two surfaces to be joined, in an oxyhydrogen or similar reducing flame, a special flux being used to still further assist in getting rid of the oxide film. See JOINTING ALUMINIUM CONDUCTORS.

Coils wound from aluminium strip are finding an increasing use for series motors and other l pr work. It has been claimed that the extra size of the bare metal is more than compensated for by the feature that for this class of work, where the pressure between adjacent turns is only a very small fraction of a volt, no insulation is required other than the film of oxide, while such a coil has a very much larger overload capacity than a copper coil, partly on account of the larger area exposed to cooling influences and partly on account of the circumstance that there is no insulation to burn or deteriorate, for, should the film of oxide break down, owing to an accidental rise of pressure, the insulating film is immediately re-formed as soon as the pressure has again assumed its normal value. It is claimed that dampness has practically no effect on the insulating qualities of the oxide film, the effect of moisture, combined with the heating effect of the coil, tending to slightly increase the thickness of the film. Pending more thorough investigation, however, it would appear hazardous to place much reliance on the permanent insulating properties of this oxide film.

Aluminium Conductors, Jointing. See ALUMINIUM; JOINTING ALUMINIUM CONDUCTORS.

Amalgam, a thick paste made by dissolving a metal (usually zinc) in mercury. In order to prevent local action in primary batteries, the zincs are always either amalgamated or covered with a layer of amalgam. A kind of amalgam is also used for bonding rails in electric traction, and is known under the trade name of the *plastic bond.* See BOND.

Ambroin, the trade name of a composition stated to be composed of fossil copal and silicates. The silicates are saturated and mixed with the copal by a special process. Ambroin is manufactured in several qualities to suit the different requirements arising in practice. Ambroin was one of the first moulded compositions introduced for electrical work, but certain of its attributes are such as to often restrict its use to work where only moderately good insulation is required. Although the manufacturers allude to its use for commutator insulation, it is improbable that it would prove so satisfactory as mica for this purpose. It has, however, a wide field of usefulness in many branches of electrical work. See also 'Moulded Insulators' under INSULATOR. (Ref. chap. vi of 'The Insulation of Electric Machines', Turner and Hobart.)

American Ton. See TON.

American Wire Gauge, an expression sometimes employed in referring to the Brown and Sharpe (B and S) wire gauge, owing to the fact that this gauge is so universally employed in the American electrical industry. See WIRE GAUGE.

Ammeter, or **Ampere-meter,** an instrument used for the determination of current strength; usually of the direct reading deflectional pattern.

['*Ammeter, or Ampere-meter*, an instrument which indicates directly, in amperes, the value of an electric current.'—I.E.C.]

If graduated in milliamperes, it is known as a *milliammeter.* Ammeters intended for rough commercial work are sometimes spoken of as *ampere gauges.* The most commonly used types of ammeters are:—

1. MOVING IRON for cc or ac (also sometimes described as *soft iron* or *electromagnetic*), in which, under the influence of the current to be measured, a piece of soft iron is moved against the controlling force of a spring or weight (see INSTRUMENT, CONTROL). If the magnetic density in the iron is low, these instruments can be calibrated to give the rms value with ac. For cc circuits, however, hysteresis introduces an error, and for a given current, the readings are liable to be different according as the current is increasing or decreasing.

2. PERMANENT-MAGNET, MOVING COIL for cc only (also known as *moving coil; d'Arsonval,* after the inventor of the principle; or *Weston,* after the American engineer who first embodied the principle in commercial instruments).—A coil of wire A (fig. 1), wound on a copper or aluminium frame, which serves to damp the movement (see DAMPING), is pivoted in the narrow air gap of a strong permanent magnet, NS. The torque exerted by the current, which is led into and out of the coil by thin ligaments, is opposed by a spiral spring (see INSTRUMENT, CONTROL). Since only a small current can be passed through the moving coil, a diverting shunt has to be used for currents exceeding, say, ½ amp. Moving-coil instruments are, for cc, the most satisfactory of all types.

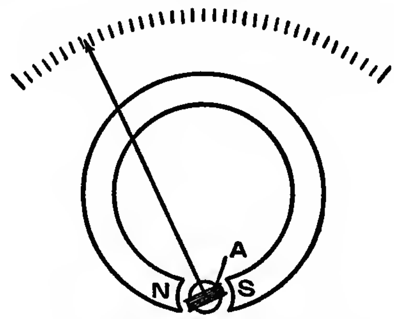


Fig. 1.—Permanent-magnet Moving-coil Ammeter

3. HOT WIRE for cc or ac (also known as the *thermal type*), depending on the expansion of a fine wire carrying either the current to be measured or a definite proportion of that current. This expansion being extremely small, considerable magnification is

necessary. Pulleys or levers are sometimes used, but the most satisfactory is the double-sag arrangement shown in fig. 2. A is the active wire carrying the current to be measured, and stretched between the terminals T_1 and T_2. It is pulled taut at its middle point by another wire C, which carries no current, and is, in its turn, kept tight by a

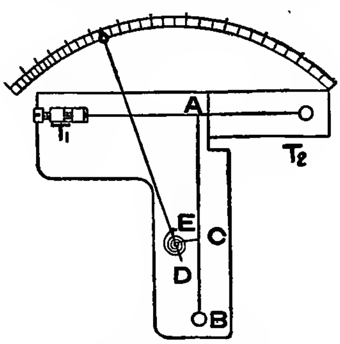


Fig. 2.—Hot-wire Ammeter

thread passing round the pulley D attached to the pointer spindle, the whole system being kept in tension by the spring E. Hot-wire instruments are equally accurate with ac or cc, but have cramped scales (since the deflection is proportional to the square of the current), and are liable to creep owing to unequal expansion of the parts. There is also the danger that they may be burnt out with even comparatively small overloads. For ammeters having a higher range than 10 amp, a shunt or transformer must be employed.

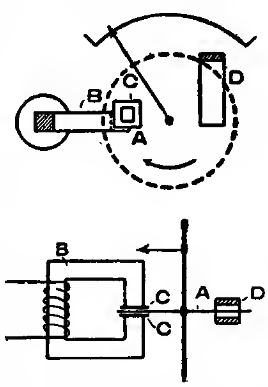


Fig. 3.—Shielded Pole Induction Ammeter

4. INDUCTION for ac only (also known as *Ferraris*, after the originator).— These are of two types: (1) *shielded-pole*, in which a disk A (fig. 3), or sometimes a drum, has eddy currents induced in it by a laminated electro-magnet B, which is energised by the current to be measured. Covering some two-thirds of the pole faces are two copper plates or shields C, and the eddy currents induced in these attract those in the disk, which consequently experiences a torque in the direction shown by the arrow. The motion is usually opposed by a spiral spring (see INSTRUMENT, CONTROL), and the oscillations are damped by a permanent magnet D (see DEAD-BEAT ELECTRICAL MEASURING INSTRUMENTS). (2) *Rotary-field.*—The arrangement of parts is in this case similar to that described for wattmeters, the necessary split phase being produced by dividing the current into two circuits, one inductive and the other non-inductive.

5. DYNAMOMETER for cc or ac (also sometimes misleadingly spoken of as *moving-coil*), in which the current to be measured flows either in series or parallel through two coils, one pivoted and the other fixed, as described in the case of dynamometer wattmeters (see WATTMETER, DYNAMOMETER ZERO TYPES). If carefully designed, such an instrument can be used indiscriminately for ac or cc, but the scale is somewhat cramped owing to the torque being proportional to the square of the current.

Dynamometer instruments are polarised, and consequently deflect to one side or the other according to the direction of the current, hence they are often provided with a zero in the centre of the scale. Such instruments are then spoken of as *central zero*, or *polarised, ammeters.* See also DUDDELL'S THERMO-AMMETER. [K. E.]

Ammeter, Idle-current. See INDICATOR, PHASE.

Ammeter, Recording. See INSTRUMENT, RECORDING.

Ammeter Transformer. See TRANSFORMER, AMMETER; TRANSFORMER, INSTRUMENT.

Amortisseur, a squirrel-cage winding located in the pole faces of the field system of an alternator. In the case of a s ph alternator the object of the winding is to decrease the penetration into the field system, of the pulsating flux due to the armature magnetomotive force. The device is also employed to improve the parallel running of alternators (which see). The term is sometimes applied to closed loops of high conducting capacity placed either between or around the poles at the surface of the gap opposite the armature. The device is usually attributed to Leblanc, and is sometimes termed a *Leblanc Amortisseur.* See DAMPING.

Amp, the preferable abbreviation for *ampere* (which see).

Amp hr, the preferable abbreviation for *ampere hour* (which see).

Amperage, a somewhat pedantic word occasionally employed to denote the current in amperes.

Ampere (abbreviation = amp), the practical unit used in the measurement of electric current, being the name of a distinguished French mathematician and physicist, who contributed largely to the foundation of the science of electrodynamics. It purports to be one-tenth of a cgs unit of the electromagnetic system. For practical purposes it may be defined as the unvarying current which, when passed through an aqueous solution of silver nitrate in a definitely specified voltameter, deposits silver at the rate of 0·001118 g per sec.

The ampere as defined above is recognised internationally, and is accordingly sometimes known as the *international ampere.*

['*Ampere,* the current which is produced by the electrical pressure of 1 volt applied to a conductor, the resistance of which is 1 ohm. The *practical* unit of electric current. It is one-tenth of the cgs unit.'—I.E.C.]

Ampere Balance (Sir William Thomson's), an instrument invented by Kelvin (then Sir William Thomson), and comprising a beam which is movable under the influence of the electromagnetic forces between coils secured to its extremities and stationary coils located just above and below the movable coils. The balance is effected by sliding a weight along over a scale carried by the movable beam. Ampere balances are standardised for various capacities, and the different instruments of the series thus resulting are termed *centi ampere balance, ampere balance, hekto ampere balance,* and *kilo ampere balance.* The instrument is chiefly suitable as a laboratory standard. See also KELVIN BALANCE.

Ampere Gauge. See AMMETER.

Ampere Hour (abbreviation = amp hr) denotes the unit of electrical quantity used in electricity supply and central station work. The term is used chiefly in connection with secondary batteries, whose output is usually rated in amp hr.

['*Ampere hour,* one ampere flowing for one hour, or its equivalent; such as four amperes flowing for fifteen minutes, &c.'—I.E.C.]

Ampere Hour Efficiency of Accumulator. See ACCUMULATOR, EFFICIENCIES OF.

Ampere Hour Meter. See METER, AMPERE HOUR; METER, QUANTITY.

Ampere Hour Motor Meter, with Magnetic Brake. See under METER, AMPERE HOUR MOTOR, WITH PERMANENT MAGNETS.

Ampere Hour Motor Meter, with Permanent Magnets. See METER, AMPERE HOUR MOTOR, WITH PERMANENT MAGNETS.

Ampere Hours per Kilogram of Plate. See ACCUMULATOR PLATES.

Ampere Meter. See AMMETER.

Ampere Meter, Galvanometer. See GALVANOMETER.

Ampere Meter, Potentiometer. See POTENTIOMETER.

Ampere's Rule, a rule by which one can determine the direction of deflection of a magnet pivoted at the centre of a coil of wire. One must imagine one's self swimming in the wire in the direction in which the current flows. If, then, one looks toward the magnet, one will find that its north pole is deflected to one's left hand.

Ampere's Theory of Magnetism. See MAGNETISM, AMPERE'S THEORY OF.

Ampere Turn (abbreviation = at), the product of the number of amperes flowing in a circuit by the number of turns in the circuit. The term thus constitutes a useful unit of mmf.

A magnetic circuit necessarily forms a closed curve; the total number of ats linked with a magnetic circuit is the algebraic sum of all the currents flowing through this closed curve from the one side to the other.

A little consideration will suffice to show these two definitions to be identical.

['*Ampere Turn,* a practical unit of mmf; the number of turns or windings of a coil multiplied by the current, in amperes, which flows through it.'—I.E.C.]

Ampere Turns, Armature, per Pole. See ARMATURE REACTION.

Ampere Turns, Primary, the product of the number of turns and the full load current, in amperes, in the primary of a transformer. This quantity is slightly larger than the secondary ats, exceeding the latter by the amount required to magnetise the core. The amount required for this purpose is the vector sum of the primary and secondary ats.

Ampere Turns, Secondary, the product of the number of turns and the full load amperes in the secondary of a transformer. See also AMPERE TURNS, PRIMARY.

Ampere Turns per Centimeter of Periphery, the number of ats in the armature winding divided by the armature circumference at the air gap measured in cm. This ratio may be employed in obtaining a rough indication of the armature strength as compared with the field-magnet strength. See ARMATURE REACTION.

Amplitude Factor, a term used to express the ratio of the maximum or crest value of an ac or emf wave to its effective or rms value. The amplitude factor of a sine wave is $\sqrt{2}$ or 1·414, indicating that the maximum value is 41·4 per cent greater than its effective value. The term is of use in connection with the stress on insulation, which is more largely dependent on the maximum (*i.e.* the crest), than on the effective value of the wave.

Amplitude of Angular Oscillation, the maximum deflection from the mean position (measured as an angle) of a body vibrating about an axis. Thus the amplitude of angular oscillation of the balance wheel of a watch is one-half the total angle swept out between the extreme positions on either side of the mean position.

Amyl Acetate Standard. See STANDARD OF LIGHT.

Amyl Alcohol. See ALCOHOLS.

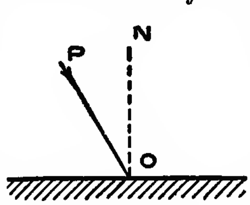
Analysis, Electric or Electrochemical. See ELECTROLYSIS.

Anchor Ear. See EAR, ANCHOR.

Anchoring Trolley Line.—In order that the ears may be relieved of the whole or part of the tension in the trolley wire, it is necessary to attach to the latter, supplementary stays or anchoring wires, fitted with suitable clamps and insulators. These carry the longitudinal stress due to the weight of the trolley wire, so that the ears have only to withstand vertical forces. Special anchor ears, provided with eyes for the attachment of the anchoring wires, are attached to the trolley wires.

Angle, Critical. See REFLECTION, TOTAL INTERNAL.

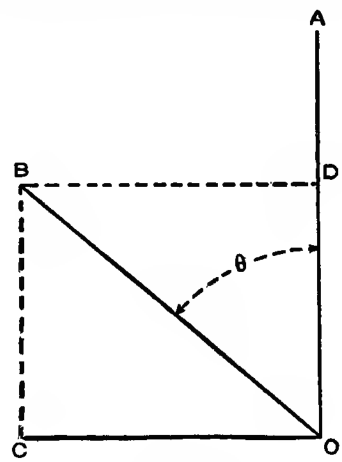
Angle of Declination, the horizontal angle between the direction of the magnetic needle when suspended to move freely in a horizontal plane, and the direction of the true astronomical north.



Angle of Incidence

Angle of Incidence.—If radiation in a direction PO strikes a surface between two media at O, and if ON is perpendicular to the boundary between the two surfaces at O, then PON is the angle of incidence of the wave normal PO. See ANGLE OF REFLECTION; ANGLE OF REFRACTION.

Angle of Lag denotes the angle by which one ac quantity is behind another, in phase (see also PHASE DIFFERENCE). The most frequently occurring case is that of an inductive circuit, where the expression *angle of lag* generally denotes the angular displacement between current and impressed emf in an inductive circuit. If OA represents the emf as a vector revolving clockwise, and OB represents the current, then the angle AOB or θ is the angle of lag. The current OB may be regarded as made up of two components, one OC lagging 90° behind OA, and the



Angle of Lag

other OD in phase with OA. The value of θ depends upon the ratio of these two components. When there are resistance and inductance only in the circuit, $\tan\theta = \frac{pl}{R}$, where $p = 2\pi \times$ frequency in cycles per sec, l = inductance in henrys, and R = resistance in ohms. When there are other energy-absorbing devices in circuit, such as motors, transformers, &c., then $\tan\theta$ = wattless component OC ÷ power component OD of current. Also $\cos\theta$ = power component OD ÷ total current OB = watts ÷ volt amperes. See also POWER FACTOR.

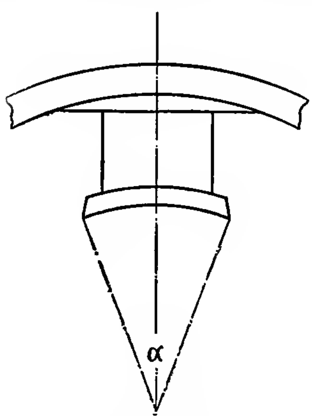
Angle of Lead denotes the angle by which one alternating quantity is in advance of another, in phase (see also PHASE DIFFERENCE). The most frequently occurring case is that of a condenser circuit or its equivalent, where the expression *angle of lead* generally denotes the angular displacement between current and emf in a condenser circuit or one having similar characteristics. The current may be regarded as the resultant of two components, one in phase with the pressure, and the other leading by 90°. The angle of lead depends on the ratio of these components. If θ be the angle of lead, we have $\tan\theta = \frac{1}{pKR}$ for a circuit containing capacity and resistance only, where K = capacity in farads, R = resistance in ohms, and $p = 2\pi \times$ frequency. See also ANGLE OF LAG.

ANGLE OF LEAD OF BRUSHES.—The term *angle of lead* is also used in connection with commutator generators and motors to denote the angle by which the brushes are moved from the neutral position.

ANGLE OF BACKWARD LEAD, the angle contrary to the direction of rotation through which the brush rocker of a commutator motor is turned in order to obtain satisfactory commutation.

ANGLE OF FORWARD LEAD, the angle in the direction of rotation in which the brush rocker of a commutator dynamo is turned in order to obtain satisfactory commutation.

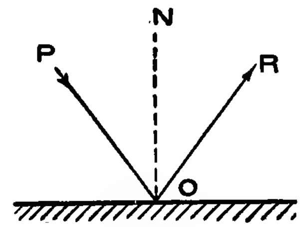
Angle of Polar Span, the angle subtended by the arc of the pole face of a



Angle of Polar Span

dynamo or motor. It is generally expressed in electrical degrees. Thus if the angle of polar span is stated to be 120°, it may be taken that the pole arc is $\frac{120}{180} \times 100 = 66{\cdot}7$ per cent of the polar pitch, τ (which see).

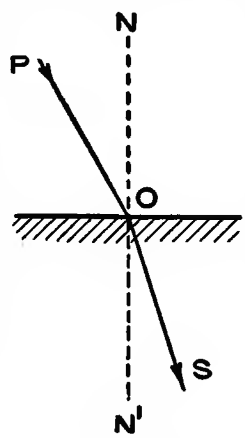
Angle of Reflection.—If PO be a wave normal of incident radiation on the surface bounding two media at O, and if optical reflection from a polished surface takes place at O, then RON is the angle of reflection. OR is the wave normal of the reflected radiation, and RON is equal to the angle of



Angle of Reflection

incidence PON, and both angles are in the same plane. See ANGLE OF INCIDENCE.

Angle of Refraction.—If PON is the angle of incidence of radiation at the surface between two transparent media, and if OS is the direction of the wave normal in the second medium, SON^1 is the angle of refraction in the second medium.



Angle of Refraction

If V is the velocity of light in the first medium, V^1 the velocity of light in the second,

Then $\frac{V}{V^1} = \frac{\sin PON}{\sin SON^1}$.

If the first medium be air, then $\frac{V}{V^1} = \mu$ where μ is the refractive index of the second medium.

Angular Acceleration of Car Wheels.—In electric traction, when calculating the torque to be exerted by the driving motors, it is necessary to allow not only for the linear acceleration of the car or train as a whole, but also for the energy absorbed in setting the car wheels and the armatures of the motors in rotation; that is, for the flywheel effect of the revolving parts. The rate at which the speed of rotation varies is called the angular acceleration, and is measured in radians per second per second or r psps (one revolution = 6·28 radians). The effect of angular acceleration is that the apparent mass of a train exceeds the true mass by from 6 to 10 per cent. Carter deals clearly with the matter in a paper entitled 'Technical Considerations in Electric Railway Engineering', read before the Institution of Electrical Engineers on January 25, 1906.

Anion. See ELECTROLYSIS.

Annealed Copper. See COPPER.

Annealing Laminations.—Laminations for use in the construction of dynamo electric machinery should be annealed from a temperature of some 850° to 950° C. The higher the temperature from which the laminations are annealed, the lower will usually be the hysteresis loss (which see). But when heated to temperatures above 900° to 950° C. or thereabouts, the laminations are apt to stick together, hence this temperature constitutes the upper practicable limit. Naturally the limit varies with different grades of iron and steel.

Annunciator, a mechanism which indicates automatically through which of a number of similar circuits a signalling current has been sent. In electric-bell and telephone installations it frequently takes the form of a small coloured disk which is released electromagnetically by the current. There is one disk for each circuit, but only one bell for all the circuits on the same board. Such a type is termed a *drop annunciator.*

['*Annunciator*, an apparatus containing a series of signals for indicating which of several circuits is making the call.'—I.E.C.]

Annunciator Board, the board on which the annunciators are fixed. See ANNUNCIATOR.

Anode.—

['*Anode.*—(*a*) In an electrolytic cell, the conductor, through the surface of which the current enters the liquid.

'(*b*) In a primary cell, the metal (usually zinc), through which the current enters the electrolyte.

'(*c*) The terminal by which the current enters a cell or other apparatus, such as a vacuum tube, &c.'—I.E.C.]

See also ELECTROLYSIS.

Answering Jack.—*Jack*, like the nautical term *jigger*, means any little thing which helps. In telephony a jack is a species of circuit maker, or connector, and is usually of the sliding, spring-contact type. A jack forms an essential part of each subscriber's circuit in an ordinary telephone exchange.

Antenna, the elevated conducting system of a wireless telegraph station. The simplest form of antenna, or aerial wire, is a single wire insulated at the top end, where it hangs from a mast, by an ebonite or porcelain insulator, and throughout its length, by the air. Its lower end is connected to the sending or receiving instruments, which in their turn are connected to earth or to a lower capacity area. The wire may be vertical or inclined at any angle. If the latter, it will receive and transmit most strongly from or to the direction in which its lower end points. Different forms of aerial conductor are used by different companies. If great power has to be sent out, *e.g.* from a long-distance station, the area of the antenna must be large in order that its charge, and consequently the energy sent out, may be large. Thus at transatlantic stations the antenna consists of a horizontal rectangle of parallel wires 100 m and often more in length, at a height of 50 m or more above the ground, connected by a number of inclined wires at one end to the instrument room (Clifden); or of a steel tube 1 m in diameter by 140 m high (Machrihanish). Up to 150 miles range, a single wire about 50 m high is sufficient. The Lodge-Muirhead system uses two large areas of wire in form of a Maltese cross, in which case less height is required.

BENT ANTENNÆ.—Garcia, Marconi, De Forest, and others have shown that an aerial wire having a horizontal part extended in one direction from the top of the vertical section, has directive properties as a radiator and collector. Marconi finds that the radiation is a maximum in the opposite direction to the horizontal part, and a minimum at right angles to it. The same is true for reception from these directions. Zenneck has shown mathematically that this difference is due to the fact that on land, at least, owing to earth resistance, the incoming lines of force are not vertical, and that there is therefore a horizontal component which is absorbed by the horizontal wire and added to that of the vertical. Somewhat similar reasoning would probably explain the directive action in transmission; it does not appear to be capable of explanation on the hypothesis that the earth is perfectly conductive. (Ref. Marconi, Proc. Roy. Soc., A, vol. lxxvii, 1906; also Zenneck, Science Abstracts, 1908, and J. Erskine-Murray, 'Handbook of Wireless Telegraphy', 2nd ed.

RECEIVING ANTENNA, the elevated conductor used at a wireless telegraph station for concentrating the current from the transmitting station on the detector circuit. In general, one aerial is used for both transmitting and receiving. It was, however, shown experimentally by Marconi in 1899, and theoretically by Rudenberg in 1908, that the height of the aerial for receiving, may be very small if its resistance and the resistances of the other receiving circuits be low. Marconi succeeded in receiving signals over a distance of about 30 miles (between Niton and Poole Harbour) on an aerial consisting of an inverted zinc can, some 2 m high, inside which was a similar but smaller cylinder, connected to earth, the two forming the condenser of an oscillating circuit. The apparatus is described in Sewell's 'Wireless Telegraphy' and in patent specifications. Rudenberg (Ann. der Physik, 3rd March, 1908) shows mathematically that if the resistance of the receiving circuit be only 1 ohm, the most advantageous height for the aerial is $\frac{1}{30}$th of the wave length of the received waves.

Anti-induction Telephone Cable. See TELEPHONE CABLE.

Anti-inductive Load. See INDUCTIVE LOAD.

Anti-magnetic Shield. See SHIELDING OF ELECTRICAL MEASURING INSTRUMENTS.

Antimony (chemical symbol = Sb), a metal whose specific resistance as determined by Matthiesen is 35·2 microhms per cu cm at 0° C. Its resistance increases by 0·39 per cent per degree Centigrade increase in temperature. Its specific heat is 0·049, and its melting-point is 440° C. Its sp gr is 6·7.

Aperiodic.—

['The motion of the moving part of a mechanism is said to be aperiodic when it does not overshoot the mark on taking up a new position. Not to be confused with *dead-beat* (which see).'—I.E.C.]

See also DAMPED.

Aperiodic Electrical Measuring Instruments. See DEAD-BEAT ELECTRICAL MEASURING INSTRUMENTS.

Aperiodic Galvanometer. See GALVANOMETER.

Apparent Efficiency denotes the ratio between the watts output of a motor or transformer and the volt-amperes input. The apparent efficiency is equal to the true efficiency multiplied by the pf of the input. See also EFFICIENCY.

Apparent Power. See APPARENT WATTS.

Apparent Resistance. See RESISTANCE, APPARENT.

Apparent Watts denotes the numerical product of the volts and amperes in a circuit, regardless of the phase relation of current and emf. *Apparent power* and *volt amperes* are synonymous terms with the above. It is often convenient to rate generators or transformers in *kilovolt amperes* (or kva) rather than in kw, this expressing the heating limit of output of the apparatus. See also POWER FACTOR.

Applied emf. See ELECTROMOTIVE FORCE, IMPRESSED.

Applied Pressure. See ELECTROMOTIVE FORCE, IMPRESSED.

Applied Voltage. See ELECTROMOTIVE FORCE, IMPRESSED.

Arago's Disk.—Arago discovered that if a current be made to flow from the centre of a circular disk to a point on its circumference while placed between the poles of a horseshoe magnet, the disk tends to rotate. The contact at the circumference was a pool of mercury, and that at the centre consisted of the bearing of the shaft on which the disk was mounted. See ARAGO'S ROTATIONS; FARADAY'S DISK.

Arago's Rotations, a group of experiments first carried out by Arago, of which that described under Arago's Disk (which see) is typical. The entire group of experiments, commonly termed Arago's Rotations, are clearly described at p. 421 of Dr. S. P. Thompson's 'Polyphase Electric Currents'.

Arc.—When two conducting electrodes, connected to the two poles of a source of electric energy, are brought into contact, and are then subsequently withdrawn, a bridge of conducting vapour of the material of which the electrodes consist, is formed, and by this means the current is enabled to flow across the intervening gap. The passage of the current under these conditions, is termed *arcing*, and the vapour path by which the current is conducted is termed an *arc*.

'An *Arc* is the phenomenon of conduction of electricity by the heated vapour or vapours of the electrode' (Trans.A.I.E.E., p. 1058, vol. xxvi, 1907).

['*Arc*, a discharge, continuous or alternating, of electricity through a gas, in which the material of one or both the electrodes is volatilised, and takes part in the conduction of the current, accompanied by a brilliant light.'—I.E.C.]

BALLASTING RESISTANCE OF THE ARC.—In order that it may be possible to maintain an arc in a steady condition, it is usually necessary to insert a certain amount of resistance in the circuit, in series with the arc. This is termed *ballasting resistance.* The necessary value of this resistance depends upon many different conditions, including the nature of the electrodes, the length of the arc itself, the magnitude of the current flowing, &c.

Counter emf of the Arc.—The resistance of the arc being presumably made up of two portions, that due to the resistance at the edge of the carbons and that due to the vapour of the arc, the resistance of the whole should be expressible in the form $r = a + bl$, where r is the resistance of the arc, l is the length of the arc, and a and b are constants. It is known, however, that the values of the constants a and b vary according to the value of the current through the arc. It has therefore frequently been suggested that there is present in the arc something in the nature of a back or c emf.

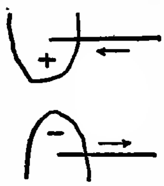


Fig. 1.—Positive and Negative Carbons

Positive Carbon.—The positive carbon of the arc is defined as the carbon at which the current enters the incandescent vapour of the arc (see fig. 1).

Crater, the brightly incandescent depression, indicated at c in fig. 2, which is formed at the tip of the positive carbon, and is the main source of light in the case of the cc carbon arc.

Negative Carbon.—The negative carbon is that by which the current leaves the stream of incandescent vapour.

Mushroom.—This is a projection which sometimes forms at the end of the negative carbon in an arc, especially when the current

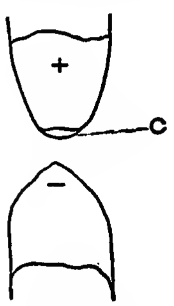


Fig. 2.—Crater, c

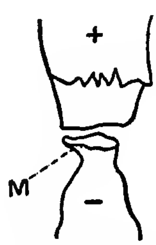


Fig. 3.—Mushroom, M

is too great. It is frequently due to the presence of impurities in the carbons, which deposit on the negative carbon in the form of a fusible slag. The formation is indicated at M in fig. 3.

The phenomena occurring at the arc are complex, and are as yet none too well understood. Certain rather indefinite terms are employed to indicate the various states of the arc:—

Silent Arc.—A silent arc is one which, when burning under normal and satisfactory conditions, is practically noiseless.

Hissing Arc.—When the current through an arc is too great, a sharp 'hissing' noise occurs. According to Mrs. Ayrton, this is due to the fact that the crater becomes too great to occupy only the end of the positive carbon, and begins to extend down the sides, the air meanwhile getting free access to the crater in a way other than that normally occurring.

Humming Arc.—As the current through an arc of given length is increased, a point is ultimately reached when the arc begins to hiss (see 'Hissing Arc'.) Just before this point is reached, the arc often assumes an intermediate humming condition, giving out a musical note. This state of things is unstable, and the arc readily passes into either the silent or the hissing condition. According to Trotter, the humming of the arc under these conditions is due to the rapid whirling of the arc itself round and round the carbons.

Flame Arc.—In the pure carbon arcs the chief source of light is the incandescent crater, relatively little light coming from the incandescent vapour itself. By introducing suitable metallic salts into the cores of carbons, the vapour is rendered highly luminous and itself becomes the chief source of light. A longer arc can also be employed under these conditions, as much as 15 to 20 mm being employed in some types. An arc of this description is termed a *flame arc*, or sometimes a *luminous arc*, from the appearance of the flame-like incandescent vapour.

Metallic Arc, an arc formed between metallic electrodes. The best-known illustration of the practical utilisation of this description of arc is to be found in the magnetite arc (see Lamps, Arc). (Ref. 'The Electric Arc', Mrs. Ayrton.) [L. G.]

Arc Deflector, a plate of fireproof insulating material used in controllers and similar apparatus to prevent the arc formed on breaking the circuit, from spreading to adjacent metallic parts. Such a plate is most commonly formed of some dense composition with an asbestos base.

Arc Lamp. See Lamp, Arc.

Arc Light.—For the purposes of the 'Phœnix Fire Office Rules' [38th (1909) edition, p. 17] an arc light is defined as 'one in which the light is produced by the passage of electrical current across a gap between two conductors'. See Lamp, Arc.

Arc Lighting, Rectifier System of.—The series system of arc lighting (see Series Distribution) with h pr constant-current cc dynamos having open-coil armatures is attended with many unsatisfactory features. On the other hand, the generation of h pr ac is attended with no difficulty; but the operation of arcs on ac, particularly when joined in series, is by no means satisfactory. An attempt has, however, been made to meet the difficulty by the introduction of the Ferranti rectifier (which see). This apparatus receives s ph current from the generators and feeds an arc-lamp circuit with rectified current, through its commutator. In this way, the lamps are supplied with a pulsating unidirectional current at high pressure, on which it has been claimed that they work even better than with the equivalent cc, as the pulsations produce a certain amount of vibration in the mechanism, thereby reducing the liability to jam or stick.

The rectifier is fed from the moving secondary of its constant-current transformer, and thus automatically provides the required current regulation. There are thus secured the advantages of alternate-current generation and transformation, the economy in distribution of the series-arc system, and the good characteristics of the cc arc. In spite of these alleged advantages, however, rectifiers are now rarely employed in connection with arc lighting. See also Rectifiers.

Arc-lighting Dynamo. See Dynamo, Arc-lighting.

Arcing. See Arc.

Arcing of the Rectifier. See 'Mercury Arc Rectifier' under Rectifiers.

Arm, Bracket. See Bracket Arm.

Armacell Insulating Varnishes, the trade name of a line of insulating varnishes which, the manufacturers claim, have very high insulating properties.

Armalac Insulating Varnish.—Armalac is the trade name of a black paraffin wax the melting-point of which is said to be permanently raised by a secret process. It is manufactured into a varnish which, the manufacturers claim, remains permanently plastic and absorbs lubricating oil without suffering any impairment of its insulating properties. The manufacturers claim that although the material remains permanently plastic, it nevertheless does not fly out under the influence of centrifugal force, even when the machine is hot, and that it is consequently quite as suitable to be employed for rotors as any non-permanently-plastic varnish. (Ref. 'The Insulation of Electric Machines', chap. viii, Turner and Hobart.)

Armature, that part of a dynamo-electric machine which contains the windings in which, by virtue of magnetic induction, the emf of the machine are generated. In commercial cc machines the armature is almost

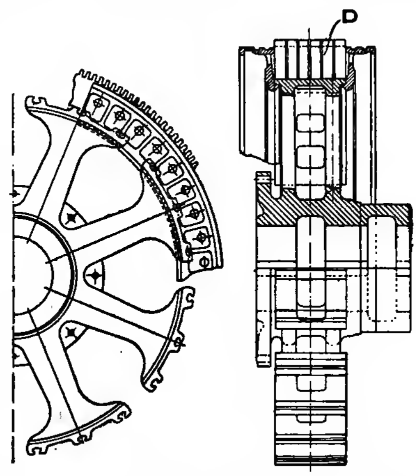


Fig. 1.—Unwound Continuous Current Armature

invariably the revolving member (*revolving armature*), while in alternators the armature is usually the stationary part (*stationary armature*), the necessary motion being given to the magnetism by the revolution of a system of magnets. See Alternator and Dynamo.

Fig. 1 represents an unwound *cc armature* of large size, and fig. 2 represents a much smaller cc armature complete with winding

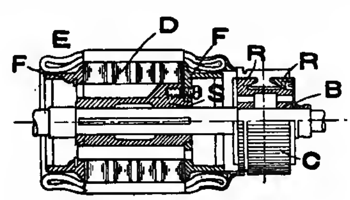
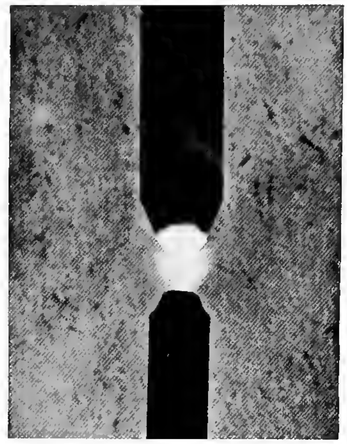


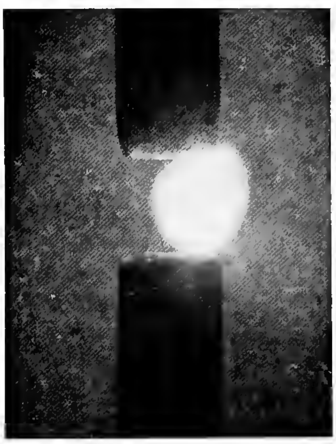
Fig. 2.—Wound Continuous Current Armature

and commutator. In fig. 2 the armature spider comprises a sleeve or spider S, and end flanges F F. In this particular instance the commutator spider B is quite distinct from the armature spider, but in many other designs it constitutes an integral part of the armature spider. The commutator clamping rings are seen at R R. The armature core D of figs. 1 and 2 is formed of core plates (also called armature laminations) of sheet

Normal Shape of Continuous-current Open Arc



Continuous-current Open Arc with a Rounded Tip on the Negative Carbon



Enclosed Arc with Solid Carbons

Alternating Arc

Continuous-current Flame Arc Burning Normally

Continuous-current Flame Arc of Short Length and in Act of Feeding

ELECTRIC ARCS

(From Zeidler and Lustgarten's "Electric Arc Lamps", by permission of Messrs. Harper & Bros.)

[*To face p. 28.*

steel (see CORE DISCS). Sometimes the armature core is built up on the shaft, but often, as in fig. 2, the shaft is pressed into the hub of the completed armature. In fig. 2 the commutator C is shown complete, as also the windings E, in place on the core D.

The following comprises the various types of armature:—

ALTERNATOR ARMATURE.—Except from the fact that it is usually stationary an

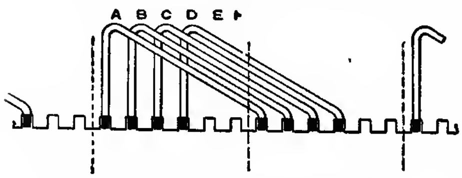


Fig. 3.—Diagrammatic Representation of Windings of a Single-phase Armature

alternator armature possesses the same essential features as a cc armature, namely, an assembly of thin sheet-steel plates in which slots have been notched to receive the coils. A distinguishing feature, however, is that the alternator coils under different poles are generally connected in series, whilst the windings on a cc armature are usually arranged in two or more parallel circuits.

SINGLE-PHASE ARMATURE.—In this type of ac armature all the coils are connected to two

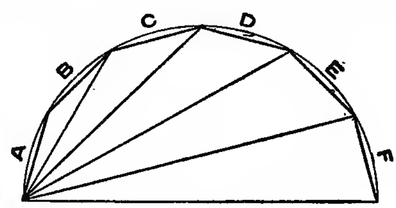


Fig. 4.—Vector Diagram of emf in a Single-phase Armature

terminals, which deliver to the system only a single ac. (See ALTERNATING CURRENT.) In usual modern practice, only two-thirds of the total number of slots of a s ph armature are wound with coils. The reason for this is readily explained by reference to fig. 3, in which an armature with six slots per pole is represented with four slots per pole wound. Owing to the different positions of, say, coils A and B, there will be a difference in phase between the emf generated in them, and consequently the resultant emf of the two coils joined in series will be less than the sum of the emf in the single coils. Fig. 4 shows the emf plotted out as vector quantities, and the following table gives the relative effectiveness of windings with various numbers of slots wound in series:—

Slots wound.	Value of emf across Coils.	Winding Coefficient.	Quantity of Copper to produce same emf.
1	1	1	1
2	1·93	0·97	1·03
3	2·73	0·91	1·10
4	3·34	0·84	1·19
5	3·72	0·74	1·35
6	3·86	0·64	1·56

The figures in the last column show that a large increase in the weight of active material is required if the conductors in a s ph machine are to be distributed over more than two-thirds the pole pitch. If, on the other hand, much less than two-thirds of the surface is wound, it is more difficult to provide a sine wave of emf. Consequently the 20 per cent greater amount of copper which is seen from the preceding Table to be required when the windings are distributed amongst two-thirds of the total number of slots, as against the amount required when the windings are concentrated in one slot, is justifiable, as also on account of the better thermal conditions thereby secured in virtue of the distribution of the winding.

THREE-PHASE ARMATURE.—In a three-phase armature, three distinct sets of coils are provided in the space occupied by every pair of poles. The emf in these coils consequently differ in phase by 120 electrical degrees. When therefore the corresponding coils on the various poles are connected up in three series groups the six ends may be arranged to provide the common three-phase system of supply. See ALTERNATING CURRENT.

TWO-PHASE ARMATURE.—In this armature, two distinct sets of coils are wound for every pole, and the emf in these coils differ by 90 electrical degrees. The two sets of coils, when connected up, are suitable for the two-phase system of ac distribution. See ALTERNATING CURRENT.

QUARTER-PHASE ARMATURE.—Because the phases in the two-phase system are displaced by a quarter of an electrical cycle, the two-phase system is designated by some engineers as the quarter-phase system. In seeking a form letter to designate three-phase machinery, many engineers adopted the letter T. Hence when a form letter for two-phase machinery was required, the letter T being already appropriated, some other letter had to be found. This is probably the reason why the letter Q and the expression *quarter-phase* have come to be frequently applied to two-phase machinery, and it should be stated that the practice has been found very convenient.

BIPOLAR ARMATURE.—In this construction the conductors pass from slot to slot on opposite sides of the machine. The disadvantages of this are that (1) a large amount of copper is thus used in inactive portions of the windings, (2) in cc, revolving, coil-wound armatures the end connections cannot be easily arranged in a uniform manner, and (3) with former wound and insulated coils the amount of preliminary bending necessary to get the coils in the slots is very apt to injure them. See also DYNAMO, BIPOLAR.

OPEN-COIL OR OPEN-CIRCUIT ARMATURE.—The usual type of cc armature has the beginning and end of adjacent coils connected to the same commutator bar. In certain h pr cc machines, more especially those used for arc lighting, so-called open-coil or open-circuit armatures are employed; the various coils are isolated from one another electrically, and are each connected to two separate bars on the commutator. As a result of this, the conductors are inactive for a portion of each revolution, but it is claimed that in certain types, the use of a commutator in which adjacent bars are not connected, facilitates sparkless collection of the current. Such types of construction, however, are rapidly going out of use.

CLOSED-COIL ARMATURE.—In this construction, now universally adopted for cc machines, each armature coil is electrically connected at the commutator to the coils situated on either side of it. In this way a complete circuit is formed of all the armature conductors upon themselves, and current introduced into or taken from the armature at the various sets of brushes is consequently divided into two parallel streams. The advantage of the closed-coil over the open-coil construction is that all the coils are always active in producing a constant cumulative pressure at the points of collection.

RING ARMATURE, the armature of a cc generator, which is made in the form of a hollow cylinder of iron, built up of thin disks, and wound with conductors which pass over the outside of the cylinder and return through the interior, the whole winding forming an endless helix, with connections at intervals to the commutator bars. Such an armature, unlike the drum type of armature, can be used in either a two-pole or a multipolar field. The construction was introduced by Gramme in 1870, and is often called a *Gramme* armature or a Gramme ring. The construction is inferior, and is now obsolete, owing to the fact that the copper under the core is inactive, and might better have been used as an active conductor under the next consecutive pole. An armature of a given size is also subject to much greater heating for a given output, and is inferior as regards commutation. A special type of ring-wound dynamo was at one time made by some Continental firms. It consisted of a ring armature revolving externally to a system of fixed magnets. The emf were induced in the inner side of the ring winding, and on the outside the copper was left bare, and served as the commutator from which the current was collected. Although a few of these machines are still at work, the type is now only of historical interest.

DRUM ARMATURE.—The drum type of winding, now almost universally adopted in cc machines, has practically superseded the ring armature. It consists in arranging the armature conductors entirely upon the surface of the armature, the conductors under consecutive poles being joined to one another by end-spiralling connections. The figures accompanying the definition of cc armature (see figs. 1 and 2 on p. 28) relate to a modern drum (or drum-wound) armature.

SINGLE-WOUND MULTIPLE-CIRCUIT MULTIPOLAR DRUM ARMATURE, a cylindrical armature core carrying on its external surface a cc winding having a number of circuits from negative to positive brushes, which is equal to the number of poles in the field magnet See WINDING, ARMATURE.

SINGLE-WOUND TWO-CIRCUIT DRUM ARMATURE, a cylindrical armature core carrying on its external surface a cc winding, having, irrespective of the number of poles of the machine, only two circuits from the negative to the positive brushes. See WINDING, ARMATURE.

SPHERICAL ARMATURE.—A spherical-shaped armature was, in the early days of electric lighting, adopted by Thomson and

Houston for their arc-lighting (and also, though less extensively, for their incandescent lighting) dynamos. The pole faces were bowl-shaped with a hole in the centre, and the magnet core was formed of a number of wrought-iron bars. This construction was claimed to give a stiff field, *i.e.* a field unaffected by reactions. In the earliest Thomson-Houston spherical armatures, the armature cores were made of iron wire and were drum-wound. In later constructions the same external appearance was observed, but the armature cores were built up of sheet-iron, and were ring-wound. As the type is so nearly obsolete, further description does not appear justified, although thousands of machines with these armatures were built in the early days of the electrical industry.

Disk Armature, a mode of construction, now obsolete, which was first introduced by Pacinotti in 1878, and afterwards adopted by Brush in his arc-lighting dynamos. The design failed for mechanical reasons, but electrically it is, in a sense, an improvement upon the Gramme ring, in that conductors on both sides of the ring are active, these being connected together by circumferential connectors from pole to pole, thus corresponding to the end connections on the modern drum armature.

Smooth-core Armature.—In early dynamos the armature windings were placed upon an iron core with a smooth surface. A chief disadvantage of this arrangement is that the magnetic drag which results from the conversion of electrical into mechanical energy or vice versa, comes upon the conductors and tends to displace them around the armature. To prevent this, metal pieces are fixed into the core so as to project, and so take up the pressure from the conductors; but these 'driving horns', as they are called, in turn proved unsatisfactory, and the smooth-core type of construction has now been generally discarded in favour of the toothed core, in which the magnetic drag comes directly upon the teeth. Another disadvantage of the smooth-core construction is that the air gap is unnecessarily long. Messrs. C. A. Parsons have continued to employ the smooth-core construction in their latest cc turbo-generators, and maintain it to be the preferable construction. Thus, on Feb. 18, 1908, Mr. Stoney of Messrs. Parsons states (Journ.I.E.E., vol. xl, p. 638): 'A great deal has been said about surface-wound armatures as against slotted. We experimented on the latter, and found that they did not give nearly as good commutation as surface-wound. Also I do not think the surface-wound are any more likely to break down. Within the last few months I have heard of several very serious cases of breakdown of slotted armatures, and, although we have had breakdowns with surface-wound, we have, considering the number of machines out, amounting to some 400 or 500, fewer breakdowns than there have been with slotted armatures.'

Slotted Armature, an armature whose surface is provided with slots for the reception of the windings. These slots may be wide open, as in the case of the armature

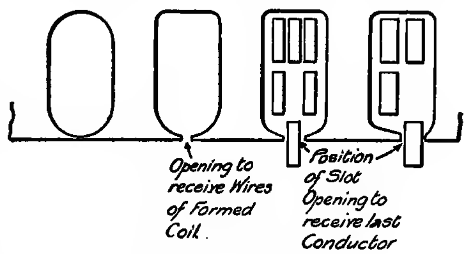


Fig. 5.—Tunnel Armature

employed in fig. 2 (p. 28) in illustrating the definition of cc armature, or they may be partly or completely closed over, in which case the armatures are sometimes termed tunnel armatures.

Tunnel Armature.—This expression, first applied to one of Siemens' early types of machines, is now used for all armatures having closed, or more generally partially closed, slots (see fig. 5). The advantage of this type of slot is that a more even flux distribution is obtained across the pole face. When it is remembered that with the open slot, the slot opening is often of about the same width as the tooth top, it will be readily understood that the adoption of the tunnel construction much reduces the eddy-current losses in the pole face. With h pr windings an insulating tube is usually inserted in the slot, and the armature conductors are drawn through. With l pr bar-windings, however, the slot opening is made sufficiently wide to allow one bar to enter, and the slot is closed by folds of varnished cambric, horn fibre, or some equivalent material, finally fixed in place by a wooden wedge. A disadvantage of the tunnel armature is that the reactance of the coil is increased, but provided the slot is not completely closed, this increase is not very appreciable.

CORELESS ARMATURE, a type of construction used by Mordey and Ferranti on their early alternators, and now obsolete. Two crowns of field magnets were mounted opposite to one another, and separated by a matter of $\frac{3}{4}$ in. or 1 in. In this gap, copper ribbon was wound in a series of coils to form the armature. In the Mordey machine the magnets revolved, while in the Ferranti type the copper ribbon winding formed the rotating member. There were certain mechanical differences in the two constructions; but as they are both now obsolete they need not be further described. (Ref. 'Dynamo Electric Machinery', vol. ii, pp. 111 and 160, Thompson.)

SIEMENS 'H' OR SHUTTLE ARMATURE, a type of armature construction introduced by Werner Siemens in 1867 but now obsolete, except for magnetos and toy dynamos. The armature stampings took the form of a letter H (see fig. 6), the armature coils all being wound together in the two large slots thus formed. The armature was also known as the shuttle type of armature because of its resemblance to the shuttle used in weaving.

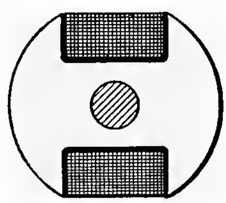


Fig. 6.—'H' Armature

HETEROPOLAR ARMATURE, an armature suitable for use with a heteropolar magnet system, *i.e.* an armature on which the conductors are so disposed as to generate the correct voltage when they are alternately brought under the influence of N and S poles. The actual emf is an alternating one, which may be rendered continuous by the use of a commutator. The usual types of cc and ac armatures are heteropolar.

WIRE-WOUND ARMATURE, the armature of an electric generator or motor which is wound with wire, in contradistinction to one of which the winding consists of bars. A section through the slot of a wire-wound armature is shown in fig. 7.

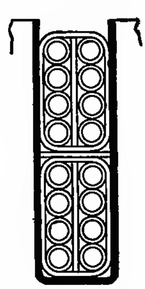


Fig. 7.—Wire-wound Armature

BAR-WOUND ARMATURE, the armature of an electric generator or motor which is wound with bars of copper. These bars are usually of elongated rectangular section, as indicated in fig. 8, which is a section through the slot of a bar-wound armature. See WINDING, BAR.

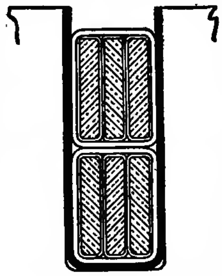


Fig. 8.—Bar-wound Armature

STRIP-WOUND ARMATURE, one in which the active parts of the windings are strip copper.

SURFACE-WOUND ARMATURE, an armature the core of which has a cylindrical surface on which the windings are secured. The windings are held in place by external bands. See also SLOTTED ARMATURES.

POLE ARMATURE, an obsolete type of armature construction in which coils of many turns were wound upon a few spider-like projections from a central disk. Some early Westinghouse arc-lighting machines were constructed in this manner. The type shades into the slotted-armature construction with one slot per pole, and it is difficult to mark the dividing line. [H. W. T.]

['*Armature* (originally the pole pieces attached to a lodestone)—

'(*a*) Of a permanent magnet. An iron bar for completing the magnetic circuit; sometimes called a *keeper*.

'(*b*) Of a simple electromagnetic mechanism. The iron part of the magnetic circuit which is not covered with wire; it is generally set in motion by an electromagnet.

'(*c*) Of a generator. That part of the machine which is acted upon inductively by the magnetic flux; and from which the induced current is transmitted to the terminals.

'(*d*) Of a motor. That part of the machine which receives the current, and is acted upon inductively by the magnetic flux. In cc machinery it usually rotates, in ac machinery it is sometimes stationary. See STATOR and ROTOR.'—I.E.C.]

Armature, Divisibility of.—The external armature of an alternator is occasionally arranged so that it can be divided into two or more parts, in order to facilitate transport or erection.

The iron core and supporting frames are built in segments, and the winding must be arranged so as to be divisible at the same points. In the case of a s ph armature the usual winding is suitable, since the coils do not overlap, and there are thus a number of places (equal to the number of pairs of poles) which are not crossed by any end connections and where the division can be made. In a three-phase winding, as usually carried out, the end connections are disposed in two different planes; in this case the coils overlap, so that no point of the periphery is free of end connections. It is in this case necessary, if the armature is to be divisible, to arrange the end connections in three different planes instead of in two. There are thus obtained a number of points (equal to the number of pairs of poles) where the armature can be divided.

Armature, Neutral Relay.—The moving piece of soft iron in a relay is neutral when not polarised.

Armature, Polarised, in telegraphy a piece of soft iron kept in a magnetised condition by proximity to a permanent magnet. Used in certain forms of relay (which see).

Armature, Rotational Energy of. See ROTATIONAL ENERGY OF ARMATURE; ANGULAR ACCELERATION OF CAR WHEELS; ENERGY, KINETIC, OF ARMATURE.

Armatures, Testing of. See TESTING ARMATURES.

Armature Ampere Turns. See ARMATURE REACTION.

Armature Ampere Turns per Pole. See ARMATURE REACTION.

Armature Back Ampere Turns. See ARMATURE REACTION.

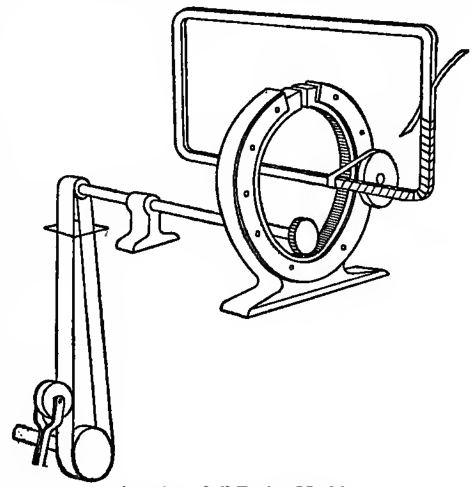
Armature Banding Lathe, a machine specially built for applying the binding wires to armatures. It is geared to revolve the armature slowly, so that the wire can be wound on taut and close to the previous layer. It is readily started and stopped by a treadle, which generally actuates a friction clutch on the driving pulley.

Armature Bars, those conductors of an armature winding which are arranged on the periphery (or in slots at the periphery) and parallel to the shaft. Generally confined to cases where the conductors are each of relatively considerable cross section. See also 'Bar-Wound Armature' under ARMATURE.

Armature Bore. See BORE OF ARMATURE.

Armature Coil. See COIL, ARMATURE.

Armature Coil Taping Machine.—Several machines have been invented for taping armature coils. They consist essentially of a device which revolves a coil of tape around the conductor, in such a direction that the tape is unwound from the coil and rewinds itself on the conductor. The speed at which the conductor is fed through the machine will determine the overlapping



Armature Coil Taping Machine

of the tape. An armature coil taping machine is shown in the figure. (Ref. 'The Insulation of Electric Machines', chap. xix, Turner and Hobart.)

Armature Conductor. See CONDUCTOR, ARMATURE.

Armature Cooling Surface. See COOLING SURFACE.

Armature Core. See CORE, ARMATURE.

Armature Cross Ampere Turns. See ARMATURE REACTION.

Armature Cross Flux, the cross field set up by the current in armature winding. See ARMATURE REACTION.

Armature Flux. See FLUX, ARMATURE.

Armature Hub, the cast spider upon which the armature core plates are assembled, and which, in addition to affording mechanical support for the armature core plates, provides a means for a central admission of air to ventilate the machine. See SPIDER; SLEEVE FOR ARMATURE CORE.

Armature Interference, the effect of the armature current in modifying the magnetic field due to the field-magnet windings. See ARMATURE REACTION.

Armature Laminations. See CORE DISCS.

Armature Leakage Flux. See FLUX, ARMATURE.

Armature (of Permanent or Electromagnet). See MAGNET KEEPER.

Armature Reaction, the influence of

the armature current in modifying the magnitude and distribution of the magnetic field due to the magnet windings. The armature reaction is primarily proportional to the armature ats.

Armature Ampere Turns, the product of the number of turns in the armature winding $\left(= \frac{\text{number of conductors}}{2}\right)$ by the current flowing in each turn.

Armature Ampere Turns per Pole, the number of armature ats divided by the number of poles on the machine; it is this number, sometimes termed the *armature strength*, which is usually considered in dealing with armature reaction.

It is convenient to distinguish between the armature reaction of cc machines and the armature reaction of alternators, although many of the terms employed are used in both cases.

Armature Reaction of cc Machines.—The following treatment is more immediately applicable to cc machines. Armature reaction affects the magnetic field in two ways:—

1. Cross Field or Cross Flux, the field due to those turns which are under the pole face, and which tend to produce a magnetic flux along the pole face, the general direction of which is at right angles to the main flux; this hypothetical field is indicated in the figure by A B C.

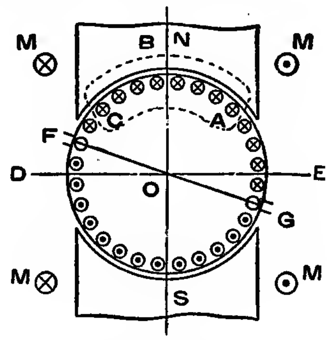
Armature Cross Ampere Turns, the number of armature ats causing the cross field, and equal to the number of conductors between A and C (of the figure) multiplied by the current per conductor.

Cross Magnetising Effect, or Distortion of the Magnetic Field.—The effect of the hypothetical field A B C is to strengthen the main field under pole tip (A), and to weaken it under pole tip (C). This effect is variously known as the *cross magnetising effect*, or as the *distortion of the magnetic field.*

Cross Induction, the increase in the number of lines per sq cm in the air gap at A over that at C.

2. Neutral Axis of Commutation, the line D E which bisects the angle between adjacent pole tips. If the brushes are displaced from the ends of this line and take up a position, say F G, then F G is called the *diameter of commutation.*

Armature Back Ampere Turns.—It is evident that the current in those conductors included in twice the angle G O E are acting in opposition to the magnet ats shown at M, M, M, M. These ats, namely the number of conductors contained in twice the angle by which the brush is displaced from the neutral point, multiplied by the amperes per conductor, are called the *armature back ats.* These turns act immediately in opposition to the field ats, and proportionately weaken the main magnetic field. They are therefore also known as *demagnetising turns.*



Armature Reaction

Demagnetising Effect, the effect exerted on the main field by the back ats.

Resultant Magnetic Field of the Dynamo, the actual magnetic field existing in the dynamo, and due to the combined effect of the magnet ats and the armature cross ats and back ats.

In comparing the armature reaction of different machines it is sometimes considered sufficient to merely compare the *ratio of field ats to armature ats.* In each case this ratio is obtained by dividing the ats on one pole of the field magnets by the number of armature ats per pole. [W. B. H.]

Armature Reaction of Alternators, the armature ats which tend to distort and to diminish or augment the effect of the ats on the field magnet. The value is sometimes reckoned numerically as follows:—

$$\frac{0{\cdot}707 \times I \times T \times p}{s}$$

where

I = current per phase,
T = turns per pole per phase,
p = number of phases,

and

s = product of the distribution and pitch factors of the winding.

This value of ats, combined at the proper phase angle with the field ats, gives the value of the ats available for producing useful flux.

In generators, besides distorting, a leading current helps, and a lagging current opposes, the field mmf; and

In synchronous motors, besides distorting, a leading current opposes, and a lagging current helps, the field mmf. Instead of the expression $\frac{0{\cdot}707 \times I \times T \times p}{s}$ for the armature reaction, various designers employ other expressions which are more appropriate to their individual methods of calculating. In Parshall and Hobart's 'Electric Machine Design' a simple and reliable method is described.

Three-phase Reactions.—The action of the three-phase currents in an alternator is to produce a resultant field which is practically uniform, and which revolves in synchronism with the field system (see Field, Rotating). Because of its uniformity, the resultant three-phase reaction produces no great increase in the load losses of the machine, the small additional losses which are present being due to windings not being placed actually in space at 120°, and to the local leakage in the teeth.

Single-phase Reactions.—Unlike three-phase currents, a s ph current in an alternator armature produces a periodic disturbance of the flux through the machine. In the magnet system this disturbance is of twice the normal frequency, while in the armature core it is the same as the normal frequency. In both cases the eddy currents which are set up, produce a marked increase in the load losses, and thus tend to give the machine a higher temperature rise on s ph loading. Designers continue to be singularly heedless of these s ph reactions, and many cases continue to arise of unsatisfactory s ph alternators.

The s ph reactions have the further effect of distorting the wave form of the machine.

[H. W. T.]

Armature Resistance, the resistance of the armature winding measured from brush to brush. In two-pole armatures and in wave-wound multipolar armatures there are two circuits in parallel from positive to negative brushes; the armature resistance is then equal to the resistance of the total length of conductor used in the winding, divided by 4. In lap-wound armatures the number of circuits in parallel is equal to the number of poles; the armature resistance is in this case obtained by dividing the resistance of the total length of conductor by the number of poles squared. See also Internal Resistance of Armature.

Armature Spider. See Spider; Armature Hub.

Armature Stampings, the sheet-steel stampings which are built up to form the armature core. See Core Discs; Core, Armature.

Armature Strength. See Armature Reaction.

Armature Teeth. See Teeth, Armature.

Armature Winder. See Winding, Forming, and Spreading Machinery.

Armature Windings. See Windings, Armature.

Armouring of a Cable. See Cable.

['*Armouring of a Cable*, a protective metallic covering of wires or tapes, usually of iron or steel (verb: to armour).'—I.E.C.]

Arno Single-phase Motor, a type of s ph induction motor forming the subject-matter of B.P. No. 21,484 of September 3, 1898. It consists of an ordinary induction motor with a uniformly distributed s ph stator winding and an ordinary three-phase star-connected rotor winding connected through three collector rings to three resistances, which are subdivided into several steps so that they may be cut out gradually as the motor comes up to speed. The specification contains two claims, the first claiming an asynchronous monophase motor, which can be started without the employment either of a rotating magnetic field or of any other starting gear, its stator being fitted with only one set of coils, through which a single monophase current flows, the same being sufficient to start the motor from rest if a convenient additional resistance be inserted into the closed-coil armature (rotor), and if a small impulse be imparted thereto. The second claim is 'for a method of imparting the initial impulse necessary to start motors constructed according to claim 1, by rendering momentarily unsymmetrical the arrangement of the rotor coils instead of by hand'.

For far more important types of s ph motor, see article on Single-phase Motors.

Arnold Single-phase Electro-pneumatic Traction System. In this system, s ph induction motors are employed. Both the stator (external part) and the rotor are arranged so that they can revolve. The one element is coupled to one of the elements of a rotary air compressor, and the other is coupled to the driving wheels of the vehicle. Even when the vehicle is at rest, the motor is kept running for the purpose of driving the air compressor. The store of compressed air is available to assist in propelling the car. Since the motor is always running at normal speed (*i.e.* since the *relative* speed of its two elements remains practically constant), the inferiority of the s ph motor in the matter of starting torque is overcome. (Ref. Trans. A.I.E.E., vol xix, p. 1003.)

Arnold Winding. See Windings, Armature.

Aron Clock Meter. See Meter, Aron Clock.

Arrester, Lightning. See Lightning Arrester.

Artificial Line. See Line, Artificial.

Artificial Magnet. See Magnet, Artificial.

Artificial Solvents.—Acetone, ether, amyl acetate, chloroform, carbon tetrachloride, carbon bisulphide, have been suggested as suitable solvents for varnishes, but only the latter has yet found any extended use for thinning insulating materials. Acetone is a good solvent for nitrocellulose, and finds some use in the manufacture of celluloid varnishes. See Carbon Bisulphide.

Asbestonite, the trade name of a fibrous moulded composition that is manufactured in several qualities. Some of the qualities resemble vulcanised fibre, being hard and tough, though they do not absorb moisture so readily. See also 'Moulded Insulators' under Insulator.

Asbestos.—Asbestos is a variety of the amphibole or hornblende family of minerals found in Italy, Canada, South Africa, and Russia, the best qualities being found in Italy. It consists chiefly of silica, magnesia, alumina, and ferrous oxide, but the proportions of each vary considerably. It is of a hygroscopic nature but a good non-conductor of heat, and infusible except at very high temperatures. Heating to redness renders it very brittle, entirely destroying the flexibility of the fibres; the reason being that the moisture of crystallisation is driven off. It has poor insulating properties, but the best asbestos can be spun into a yarn and used for lapping and braiding wires. Its heat-resisting property has led to its use in the manufacture of 'fireproof' and 'fire-resisting' coverings, and it is also extensively used in the manufacture of many moulded insulators.

Asbestos Wood, the trade name of an asbestos composition that can be moulded to almost any shape. The manufacturers claim that it is tougher than either marble or slate, and withstands the action of an arc better. (Ref. Elec. World, N.Y., April 27, 1907.)

Asphalt (sometimes termed **Asphaltum),** a mixture of hydrocarbons occurring under a great variety of conditions, and varying greatly in composition. It is unaffected by water, is permanent, and is now used commercially for the manufacture of cable conduits.

Assessment Tariff, a method of charging electricity consumers which has been introduced at Norwich by Mr. Long, the city electrical engineer. It is provided that private consumers may elect to be charged either at a flat rate (see 'Flat Rate System' under Tariff Systems) of $4\frac{1}{2}d.$ per kw hr, or on the assessment tariff, which consists of a fixed charge of 12 per cent upon the net assessment of the house and 1*d.* per kw hr for all electricity consumed. See also Tariff Systems. (Ref. Handcock and Dykes's paper, entitled 'Electric Supply Prospects and Changes', read before the I.E.E. in 1908.)

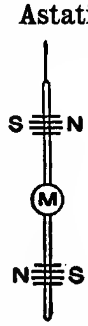
Association Cables. See Cables, Association.

Astatic.—

['*Astatic*, a system of magnets or coils is said to be astatic when the polarities of its parts are so adjusted that the polarity of the whole is zero, and no directive effect is exerted on the system by a uniform magnetic field.'—I.E.C.]

Astatic Circuit. See Circuit, Astatic.

Astatic Needle.—Two magnetic needles of equal moment are mounted in opposition on a light support. The whole system being suspended by a torsionless fibre, there will be no tendency to assume any fixed direction in a uniform magnetic field such as the earth's. Each needle is commonly composed of a number of small units. The astatic needle illustrated in the figure, is provided at its centre with a mirror M, and serves as the moving element of a reflecting galvanometer.



Astatic Needle

Astatic Switchboard Integrating Meters. See METER, SWITCHBOARD INTEGRATING.

Asynchronous.—

['*Asynchronous*, a term applied to an ac generator or motor, the speed of which has no fixed relation to the frequency of the current.'—I.E.C.]

Asynchronous Generator. See GENERATORS.

Asynchronous Motor. See MOTOR, INDUCTION; MOTOR, COMMUTATOR.

At, the preferable abbreviation for *ampere turn* (which see). This abbreviation constitutes an exception to the rule to which most of the abbreviations in this Dictionary conform; in that, when employed in the plural, an *s* is added.

Atkinson Cast Bond. See BOND.

Atkinson Motor. See SINGLE-PHASE MOTORS.

Atkinson-Schattner Maximum Demand Indicator. See INDICATOR, MAXIMUM DEMAND.

Atm, the preferable abbreviation for *atmosphere*.

Atmospheric Conduction. See ATMOSPHERIC ELECTRICITY.

Atmospheric Discharge. See ATMOSPHERIC ELECTRICITY.

Atmospheric Electricity.—The chief electrical phenomena of the atm are the sudden discharges termed lightning; the less concentrated but still rapid discharge constituting the aurora borealis, and the slow and usually invisible discharges which are continually taking place from all elevated conductors, such as tree tops, masts, and steeples, into the air. Lord Kelvin showed by means of his electrometer that the potential gradient in the atm may amount, in fine weather, to some hundreds of volts per ft. above the earth's surface, the air being positive to the earth. This accounts for the slow and usually invisible discharges above mentioned. In stormy weather the potential gradient may be reduced to zero or even reversed. It is also affected by the visibility or invisibility of the sun and moon, whether caused by clouds or by the diurnal motion of the earth. The conductivity of the air, which at the earth's surface is very low (about 2×10^{-25} cgs), is also variable. The conductivity of a gas is a quite different quantity for a discharge between electrodes and for an electrodeless discharge, the pressure being very much smaller in the latter case (see 'Recent Researches in Electricity', J. J. Thomson). At a 1 pr, such as exists about 40 miles up, the resistance may be as low as 10 ohms per cc. [J. E-M.]

Atomic Energy. See ENERGY.

Atonic Interrupter. See INTERRUPTER, ATONIC.

Attachment Plug, a metal plug forming the terminal of a connecting wire or flexible in telephony.

Attraction and Repulsion, Electrodynamic. See ELECTRODYNAMIC ATTRACTION AND REPULSION.

Au, the chemical symbol for *gold* (which see).

Audion. See 'De Forest System' under WIRELESS TELEGRAPHY.

Audion Valve. See RECTIFIER.

Augmentor, Vacuum. See VACUUM AUGMENTOR.

Autogenous Welding. See WELDING, AUTOGENOUS.

Automatic Acceleration. See CONTROLLER REGULATOR.

Automatic Block System. See BLOCK SYSTEM FOR RAILROADS.

Automatic Calling, in telephony, a system by which the mere removal of the instrument from its hook or position of rest operates the call signal.

Automatic Circuit Breaker. See CIRCUIT BREAKER.

Automatic Compounding. See COMPOUNDING, AUTOMATIC.

Automatic Cut-in and Cut-out for Accumulator. See BATTERY CUT-OUT.

Automatic Cut-out, a device for automatically breaking a circuit on overload or under some other condition which it is desired to guard against. See also FUSE; 'Automatic Circuit Breaker' under CIRCUIT BREAKER.

Automatic Cut-out Relay. See RELAY.

Automatic Earth Leakage Cut-out, Wallis-Jones's. See WALLIS-JONES'S AUTOMATIC EARTH LEAKAGE CUT-OUT.

Automatic Electro-gas Block Signalling, a system of block signals in which the signals are given by gas flames controlled electrically. See also BLOCK SYSTEM FOR RAILROADS.

Automatic Electro-magnetic Brake. See CRANE, ELECTRIC.

Automatic Interrupter, a device for making a cc intermittent. It may be electromagnetically actuated, as in an electric bell or hammer break, in which case the establishment of the current energises a magnet which pulls the contacts apart and breaks the circuit again. In electrolytic interrupters the conditions at the point where the current passes into the liquid are unstable, and intermittent changes take place, either through the generation of steam bubbles or other more molecular actions, the result being a periodic variation in the current. In the mercury interrupter the rate of make and break is regulated by the speed of the independent driving mechanism (*e.g.* electric motor) which moves the contacts. See Rectifier.

Automatic Lift Controller. See Lift, Electric.

Automatic Mechanical Brake for Electric Cranes. See Crane, Electric.

Automatic Motor Starter. See Remote Control System; Starting of Motors.

Automatic Overload Switch. See Circuit Breaker.

Automatic Regulation of Dynamo Electric Machine. See Automatic Regulation of Voltage.

Automatic Regulation of Voltage.—The automatic regulation of the pressure of a cc system is generally effected by compounding the field of the generator so that its pressure remains constant at all loads, or rises slightly with the load to compensate for the drop in the mains to the supply area. (See Winding, Compound.) Where a single circuit has an excessive drop, it is usual to provide it with a special booster wound with a series field, so that as the load increases so does the applied pressure increase, while the pressure at the distant end of the circuit remains constant, or nearly constant.

Where, however, very rapid variations of pressure have to be guarded against, as, for instance, where a lighting circuit is fed from a motor generator, the motor side of which is connected to a tramway circuit, compound windings are of little service owing to the sluggishness of the field in adjusting itself to variations in the exciting ats. In such cases an automatic regulator, such as the Tirrill, has to be installed. See 'Tirrill Regulators' under Regulators, Potential.

The automatic regulation of an ac pressure is almost invariably effected by means of regulation of the exciting current, and regulators of the Routin, Thury, Tirrill or similar types are generally adopted. Various compensated windings for alternator field circuits have been brought forward from time to time; but the problem is greatly complicated by the fact that the pf of the ac circuit may vary independently of its load, and at the present time such machines are extremely rarely used. See 'Heyland Polyphase Generator' under Generator.

Special regulators are used to automatically alter the pressure as required to maintain a constant current where cc arc lamps are run in series from series dynamos of the old Brush or Thomson-Houston types. Although there are still a considerable number of such generators in use in America, they are, practically speaking, obsolete in this country. In the case of the Brush arc machines, the regulator takes the form of a number of carbon blocks, which are pressed together more or less tightly, and their resistance thereby altered, by means of an electromagnet in the main circuit; the blocks form a resistance which is a shunt to the field circuit of the machine, and as the resistance varies, the excitation, and therefore the pressure of the machine, is correspondingly altered. The regulation of the Thomson-Houston machine is effected by an electromagnet which alters the angle over which the brushes extend on the commutator of the machine; the larger the brush angle the less the pressure. A detailed description of both these machines and their regulators will be found in most good textbooks of about twenty years ago.

A further class of special regulator is sometimes used for the purpose of maintaining constant the pressure of a secondary battery. This type generally consists of a multicontact switch for altering the number of cells in circuit, operated by a small electric motor, which is switched into or out of circuit by means of a relay, the action of which is dependent upon the pressure on the mains. Such regulators are also but little used.

Automatic Regulator. See under Automatic Regulation of Voltage; Regulators, Potential.

Automatic Ring-off Signals, an arrangement by which the action of hanging up the telephone on the hook indicates automatically in the exchange the fact that the line is clear.

Automatic Stoker. See Stoker, Automatic.

Automatic Switch. See SWITCH, AUTOMATIC.

Automatic Synchroniser. See SYNCHRONISER.

Automatic Synchronising Gear. See SYNCHRONISER.

Automatic Telephone Exchange. See TELEPHONE EXCHANGE.

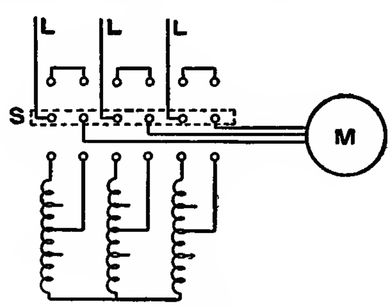
Automatic Time Cut-out. See TIME-LIMIT DEVICE.

Automatic Time-limit Device. See TIME-LIMIT DEVICE.

Automatic Transformer Switch. See SWITCH, AUTOMATIC.

Auto-Mixte System, a system of propelling vehicles. The vehicle is driven by a petrol engine, which is also coupled to a shunt-wound dynamo-electric machine. When the vehicle is at rest or running under conditions not imposing much load on the petrol engine, the latter drives the dynamo-electric machine, and the electricity generated is sent into a storage battery. But the dynamo-electric machine may, when required, be arranged as a motor, and will then drive the axles of the vehicle through a clutch and suitable gearing, receiving its energy from the storage battery. Thus for heavy loads, as in starting or hill-climbing, the dynamo-electric machine operating as a motor, assists the petrol engine in propelling the vehicle. Particulars of the equipment of some trial motor cars for the London, Brighton, & South Coast Railway are given on p. 40 of Elec. Eng. for July 2, 1908. The system is also known as the *Pieper System.*

Auto-starter, an auto-transformer (which see) or 'compensator' used for starting in-



Auto-starter

duction or synchronous motors. The auto-transformer reduces the pressure to a suitable value for starting, and a switch connects the motor to the secondary terminals. As soon as the latter has run up to speed, the switch is thrown over so as to cut out the starter and connect the motor directly to the line.

In the fig., M is a three-phase motor connected to three of the six movable contacts of the switch S; the other three of these are connected to the line L, L, L. The lower set of fixed contacts is connected to the coils of the auto-transformer as shown, and the upper set of fixed contacts connected in pairs. When the switch is in the middle position shown, the current is 'off'. Throwing its six vertical blades to the lower position, connects the motor to a lower pressure, of a value depending on the tappings connected. Throwing the switch to the upper position throws the full line pressure on the motor, and disconnects the starter. The advantage of this reduced-pressure method of starting, is that the line current taken is reduced in proportion to the square of the ratio of transformation, compared with what it would be if the motor were thrown direct on to the mains. See also SWITCH, MOTOR-STARTING; STARTING OF MOTORS.

Auto-transformer, a transformer which has only one winding for both primary and

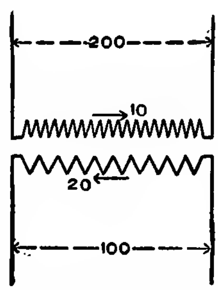


Fig. 1.—Transformer with two independent windings

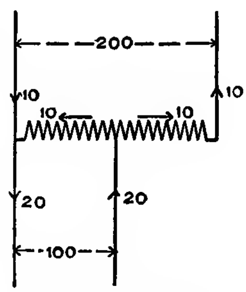


Fig. 2.—Auto-transformer

secondary. Such transformers are used where the ratio of transformation is small, as a considerable saving in copper and iron can be effected, and the whole transformer reduced in size as compared with one having separate windings.

Fig. 1 shows a 200 : 100 volt transformer having a 10 amp primary and a 20 amp secondary, the currents being in opposite directions. If we superpose these currents by using one winding only, we obtain the auto-transformer shown in fig. 2, where the winding carries 10 amp only and requires only one-half the copper (assuming the same mean length of turn). If R be the ratio of an auto-transformer, the relative size of it compared with a transformer of the same ratio and output is as $\frac{R-1}{R}:1$. For example, a 10 kw transformer of 400 volts primary and 300 volts secondary could be replaced by an auto-transformer of $10 \times \frac{1 \cdot 33 - 1}{1 \cdot 33} = 2 \cdot 5$ kw; or, in other words, the amount of material used in a $2\frac{1}{2}$ kw transformer could be used to wind an auto-transformer of 400 : 300 ratio and 10 kw output. See also AUTO-STARTER; STARTING OF MOTORS; TRANSFORMER, ADAPTER. [R. C.]

In the 1907 Standardisation Rules of the A.I.E.E., auto-transformers and compensators are defined as types of stationary induction apparatus (which see) in which a part of the primary winding is used as a secondary winding, or conversely.

['*Auto-transformer*, a transformer in which part of the winding is common to both the primary and the secondary circuits; sometimes called a *compensator*.'—I.E.C.]

Auvert-Ferrand Permutator. See PERMUTATOR.

Auxiliary Bus Bars. See BUS BARS.

Auxiliary Coil. See COIL, COMPOUNDING; COIL, COMPENSATING.

Auxiliary Flux, the magnetic field produced by an auxiliary pole or winding.

Auxiliary Poles. In cc dynamos and motors, the term auxiliary poles is sometimes loosely used to mean interpoles (which see). See MAIN POLES.

Auxiliary Starting Winding. See WINDING, AUXILIARY STARTING.

Average Current. See CURRENT, AVERAGE.

Average Voltage. See VOLTAGE, AVERAGE.

AWG, American Wire Gauge (see WIRE GAUGE). The more usual designation is B & S, or Brown and Sharpe Wire Gauge. For copper wires the use of the B & S gauge is practically universal in the American electrical industry.

Ayrton-Mather Galvanometer. See GALVANOMETER.

Ayrton-Mather Duddell Wattmeter. See WATTMETER, DYNAMOMETER ZERO TYPES.

B

B, symbol for density of magnetic flux in lines per sq cm.

B.A. Ohm, abbreviation for British Association Ohm. See OHM.

B.A. Volt, abbreviation for British Association Volt. See VOLT.

B. and S. See WIRE GAUGE.

Back Ampere Turns of Armature. See ARMATURE REACTION.

Back emf, synonymous with Counter Electromotive-force. See ELECTROMOTIVE-FORCE, COUNTER.

Back-geared Motors. See MOTORS, BACK-GEARED.

Back Pitch. See PITCH, WINDING.

Backward Lead.—The brushes of a motor which is required to run in but one direction are sometimes displaced a certain angular distance behind the neutral point. They are then said to have a backward lead. See BRUSHES, ADJUSTMENT OF; 'Angle of Backward Lead' under ANGLE OF LEAD.

Bad Earth. See EARTH.

Baking Oven. See OVEN, BAKING.

Baking Varnishes. See INSULATING VARNISHES.

Balance, Ampere. See KELVIN BALANCE; AMPERE BALANCE.

Balanced Load.—This term, applied in connection with a three-wire system, denotes equality of load on the two sides, *i.e.* the condition of zero current in the middle wire. Applied in connection with a *polyphase system* it denotes the condition of a continuous or non-fluctuating flow of power. This condition obtains when all the phases carry equal currents at equal power factors. Under these conditions we may term the system a *balanced polyphase system.*

Balanced Polyphase System. See BALANCED LOAD.

Balancer. See also THREE-WIRE DISTRIBUTING SYSTEM; BALANCER, ALTERNATING-CURRENT.—

['*Balancer*, a dynamo, pair of dynamos, motor generator, or rotary converter, arranged to maintain the equality of pressure on the two sides of a three-wire system.'—I.E.C.]

Balancer, Alternating-current, a transformer having only one winding, which is tapped at the middle point for connection to the middle wire of a three-wire system, the main terminals being connected to the outer wires. A rise of voltage on one side of the system, due to an unbalanced load, causes a greater current to flow in the half of the winding connected to that side, thus adding to the load on the lightly loaded side, whilst inducing in the other half of the winding an increased emf which causes current to flow to the heavily loaded side of the system, thus tending to equalise the pressure on both sides of the system by transferring part of the load from one side to the other. See also THREE-WIRE DISTRIBUTING SYSTEM; TRANSFORMER, ADAPTER.

Balancer Compensator. See TRANSFORMER, ADAPTER.

Balancer Transformer. See TRANSFORMER, ADAPTER.

Balancing Machine.—In balancing an armature, it is not only necessary that the weight should be equally distributed about the axis of rotation, but that, when revolving, the distribution of the weight of the armature itself and also the balance weights should be so distributed as to prevent any tendency of the armature to 'wriggle'. To balance the armature to meet these conditions, it is mounted on bearings supported on ball races, and prevented from excessive lateral movement by means of springs attached to rigid supports. When the armature is driven at high speeds through a flexible coupling, the unbalanced forces brought into play, produce movements on the two bearings, which may be recorded. A comparison of the relative movements at the two ends affords an indication of the correct position for balancing weights. Such an arrangement as this, with flexible bearings, is essential in the accurate balancing of high-speed machinery. See also BALANCING POCKETS; BALANCING TABLE.

[For a discussion of the theory of balancing machines, see American Machinist, March 10, 1906.]

Balancing Pockets. — On the inside periphery of rotor spiders and magnet wheels, recesses are cast. These are known as balancing pockets, and molten lead is run, where necessary, into one or more of them after the machine is complete, so that a good mechanical balance may he obtained.

Balancing Rings. — Equalising rings, or equipotential connections as applied to multiple-circuit armatures, are sometimes termed balancing rings. See CONNECTIONS, EQUIPOTENTIAL.

Balancing Table. — This consists of two narrow rails, erected absolutely level, on which an armature with its shaft, may be placed. As the rails are finished with a true surface, a heavy spot on the armature will cause it to turn until the armature comes to rest with the heavy spot at the bottom. This method only permits of obtaining an equal distribution of the weight about the axis of rotation. But high-speed rotors will 'wriggle' unless the balancing weights are so adjusted as to indicate on a balancing machine (which see) an accurate balance.

Ball Bearings. See BEARINGS.

Ballasting Resistance of Arc. See ARC.

Ballistic Galvanometer. See GALVANOMETER.

Ballistic Method, a method of measurement in which a reading is taken of the first swing of an instrument instead of the steady reading. A common application of the method is the ballistic galvanometer. See GALVANOMETER.

Band, Binding. See BINDING BANDS.

Band Brake for Testing Electric Motors. — If a flexible band be lapped round the pulley of a motor, and if one end be made fast to a suitable eye, through a spring balance, while the other end is attached through a spring balance to a screw tightening gear, the arrangement forms a band brake, by which the power of the motor can be measured.

If R is the radius of the pulley in m, and T_1 is the tension in kg on the slack side of the band, and T_2 the tension on the tight side, then the power, P, in hp, developed by the motor is given by the formula:

$$P = \frac{2\pi R n (T_2 - T_1)}{76}$$

where n is the speed of the machine in rps.

An improvement on this method of testing, has been introduced by Soames, whose *Absorption Dynamometer* consists of a tripod, from the head of which is suspended a balance lever supported on knife edges. The balance arrangement can be raised and lowered at will by means of a screw and hand wheel. On the balance lever are two sliding carriages and hooks, which may be set at a distance from the axis of rotation of the lever, such that when the two ends of the brake band are attached to them, the sides of the band are perfectly parallel as they pass down and under the pulley of the machine under test. The load on the machine is varied by bodily raising or lowering the balance arrangement by means of its suspending screw, and thus increasing the friction between the pulley surface and the band. Each load is measured by hanging weights on the end of the lever until the balance is horizontal.

If R is the radius in m, of the lever, from the axis of rotation to the point at which the weights are hung, W the weight in kg required to bring the lever horizontal when the machine is making n rps, then P, the hp, may be obtained from the formula:

$$P = \frac{2\pi R W n}{76}$$

if the sides of the band are perfectly parallel. Great care must be taken to ensure this, otherwise considerable errors are introduced. [C. V. D.]

Band Coupling, a coupling in which the two parts are connected by leather bands.

Banding Lathe, Armature. See ARMATURE BANDING LATHE.

Bank.—

['A number of similar pieces of apparatus grouped and connected to act together, is sometimes called a bank. Thus lamps are banked in parallel, or in series, to form a resistance; and several transformers are banked to act as a single transformer.'—I.E.C.]

Bank of Transformers. See TRANSFORMERS, BANK OF.

Bar, Armature. See ARMATURE BARS.

Bar, Commutator. See COMMUTATOR BAR.

Bar and Cable Windings. See WINDINGS, CABLE AND BAR.

Bar and Yoke Methods. — Strictly speaking, all iron-testing methods in which the endlessness of the specimen under test is produced by its insertion into a yoke, might be classed under this head. It is, however, more specifically applied to a method introduced by Prof. Ewing in order to eliminate the effect of the yoke when very permeable specimens are under test.

The test specimen is in the form of two accurately turned rods, which are united at their ends by yokes, through which they can slide. The effects of these yokes are eliminated by making two sets of observations on the specimens; in the first set the yokes are at the extreme ends, and in the second set they are a much shorter distance apart. By this means a correction is found by which the observations of H′ in the first set of readings may be corrected to true H. See TESTING, MAGNETIC; BRIDGES. (Ref. 'Magnetic Induction in Iron and other Metals', Ewing, pp. 363–365.)

Bar Armature. See WINDING, BAR.

Bar Coal Cutter. See ELECTRIC COAL CUTTER.

Bar Electromagnet, a straight electromagnet having no return magnetic circuit other than that afforded by the surrounding medium.

Bar to Bar Test. See TESTING ARMATURES.

Bar Winding. See WINDING, BAR.

Bar-wound Armature. See ARMATURE; WINDING, BAR.

Bare.—In the definitions accompanying the 1908 Home Office Regulations for Electricity in Factories and Workshops, bare is defined to mean 'not covered with insulating material'.

Bare Conductors. See CONDUCTORS, BARE.

Barometric Condenser, a variety of ejector condenser. See CONDENSER, STEAM.

Barrel Winding. See WINDING, BARREL.

Barretter, a species of hf current detector used in wireless telegraphy. Fessenden's original form consisted in a very fine wire whose temperature, and therefore resistance, was altered by the hf current received from the sending station. In later forms there is a liquid section in the circuit, into which a very fine point of wire dips, or which is itself contained by a fine capillary tube. See BOLOMETER. [J. E-M.]

['*Barretter*, an instrument in which the current to be measured, generally alternating, flows through and heats a fine wire strip or filament, and causes a change in its resistance, which is taken as the measure of the current.'—I.E.C.]

Bars, Equalizing. See EQUALIZING BARS AND CABLES.

Basket Winding. See WINDING, BASKET.

Bastian Electrolytic Meter. See METER, ELECTROLYTIC.

Bastian Lamp. See LAMPS, TUBULAR.

Battery.—The word *battery* is now more generally applied to *primary* cells, for which see Battery, Primary. While the word is also often applied to secondary cells, these are more usually termed *accumulators*, and consequently secondary cells (*i.e.* secondary or storage batteries) have been classified under Accumulators (which see). Some apparatus employed in connection with accumulators, such as boosters, are, however, exclusively described either briefly as *boosters*, or more especially as *battery boosters*, and one would probably never encounter the term *accumulator booster*. Other instances of inconsistencies in the customary use of the words *battery*, *accumulator*, and *cell* could be cited. In view of these inconsistencies, it may sometimes be necessary, in seeking a definition of a term employed in this department of electrical engineering, to consult these three headings, although an endeavour has been made to facilitate the process by liberal cross references.

['*Battery*, two or more cells connected in one circuit.'—I.E.C]

Battery, Buffer, a set of cells (*i.e.* an accumulator) arranged to take the fluctuations of load and thus prevent them from coming on the generating plant, to which the accumulator acts as a 'buffer' or cushion. Since the pressure across the terminals of a battery falls rapidly when it is giving a heavy discharge, an automatic reversible booster is employed to add its pressure in direct proportion as the battery pressure drops, and the pressure across the terminal of the combination is kept constant. See Battery-booster Set.

Battery, Daniell. See Cell, Daniell.

Battery, Lead. See Accumulator.

Battery, Line. See Accumulator.

Battery, Multiple-connected. See Accumulators in Parallel.

Battery, Primary.—In a strict sense, a primary battery is one in which, in action, one of the electrodes becomes gradually dissolved in the electrolyte, and in which the reverse chemical action does not take place when a current is passed through the cell in a reverse direction. The term *primary battery* is, however, used in a wider sense, and includes those batteries where the regeneration of the battery is possible, but of no practical utility. In many instances the negative electrode, on being redeposited, takes a crystalline or flaky form, which does not adhere to the electrode, and consequently is of no further use, although it dissolves in the electrolyte after charging is completed, thereby exhausting the electrolyte, but furnishing no useful electrical energy. See also Cell; Cell, Standard; and Cell, Voltaic.

Bichromate Battery, a single-fluid primary battery, with carbon plates as positive, and amalgamated zinc as negative electrodes. An arrangement is usually provided for lifting the zinc electrodes out of the solution when not in use, to avoid wasting of the zinc by local action. A convenient fluid is Poggendorf's solution (which see). The emf of the cell is about 2·2 volts.

Bunsen Battery, a primary battery similar to a Grove cell, in which the platinum-foil positive electrode is replaced by carbon plates. The emf of the cell is very little lower than that of the Grove cell (1·90 volt as against 1·96 volt), and the cost is much less.

Chloride of Silver Battery, a primary battery with zinc negative and silver positive electrodes. The electrolyte is ammonium chloride, and the depolariser is chloride of silver, which is usually contained in a cylinder of paper parchment surrounding the silver electrode. The emf is 1·046 volt.

Closed-circuit Battery, a battery so constructed as to maintain a low constant current in a closed circuit for a prolonged period. The Daniell cell is particularly adapted to this class of work. See Cell, Daniell.

Dry Battery, a battery in which the excitant (usually salammoniac) is kept in a more or less solid or gelatinous form by the aid of glue, flour, silicate of soda, &c., with which plaster of Paris is generally mixed. A hygroscopic substance, such as chloride of zinc, is usually added to retain the requisite degree of moisture necessary for conductivity. In such batteries, the positive is usually of the Leclanché type, viz. a carbon rod surrounded by a depolariser of dioxide of manganese mixed with graphite or carbon. The negative electrode is of zinc, which, as a rule, is cylindrical, and forms the container for the active mass and the positive electrode. In dry batteries where the exciting mass is of a gelatinous description, the positive element, with the depolarising mass, is enclosed in a porous bag of some fibrous material. The emf is from 1·46 to 1·52 volt.

Edison-Lalande Battery, a primary battery in which the negative element is iron and the positive is oxide of copper, the latter also constituting the depolariser, and becoming reduced to metallic copper when a current flows. The electrolyte is a solution of caustic soda or potash, which is usually protected from the action of carbonic acid in the air by means of a film of non-drying oil, or by sealing-in the cell. The emf is only 0·66 volt.

GAS BATTERY.—This battery was invented by Grove, and is only of theoretical interest. The positive and negative electrodes of platinum are arranged in separate glass cylinders inverted over dilute sulphuric acid in a containing vessel, and surrounded by oxygen and hydrogen gases respectively. The gases may be evolved at their respective poles by charging from another battery. On connecting the poles, a current is obtained, the pole at which oxygen has been liberated, being the positive pole.

UPWARD'S BATTERY, in which chlorine gas dissolved in water is used as the exciting fluid, is sometimes referred to as a gas battery. In this battery, the negative pole is zinc and the positive carbon rods are packed in crushed carbon.

GROVE BATTERY, a two-fluid primary battery. The positive electrode consists of a platinum sheet immersed in concentrated nitric acid contained in a porous pot. The negative electrode is amalgamated zinc immersed in an exciting solution of dilute sulphuric acid. The zinc is usually bent into U shape, nearly filling the glazed-earthenware container. Between the limbs of the U is placed the porous pot containing the nitric acid depolariser and the platinum positive. The emf of the Grove cell is 1·96 volt.

OPEN-CIRCUIT BATTERY, a battery which can only maintain a current for short periods, requiring intervals of rest to recuperate.

VOLTAIC OR GALVANIC BATTERY, a combination of voltaic cells arranged in series, that is, with the positive of one cell connected to the negative of the next, leaving a free positive pole at one end and a free negative at the other. The emf of such a battery, if the cells are similar, is the emf of one cell multiplied by the number of cells.

LOCAL BATTERY, a battery used for circuits requiring relatively large currents and governed by a relay (which see) actuated by means of a much smaller current from a distant point or station. By the use of such a local battery and relay, the loss of power consequent upon sending a large current through a long main circuit is avoided.

FULLER BATTERY.—The electrolyte may be composed of 6 oz. of sodium bicarbonate and 17 oz. of sulphuric acid dissolved in 56 oz. of water. The porous cup should contain a zinc rod immersed in a mixture consisting of 1 teaspoonful of mercury and 2 teaspoonfuls of salt, and enough water to fill up to within some 5 cm of the top. The negative element is a carbon plate placed in the outer solution. The zinc maintains itself in a well-amalgamated condition owing to the presence of the mercury. In an alternative recipe, bichromate of potash is employed instead of sodium bicarbonate. See also MEIDINGER CELL. [F. C.]

Battery, Ringing. See RINGING BATTERY.

Battery, Secondary. See ACCUMULATOR.

Battery, Storage. See ACCUMULATOR.

Battery, Talking.—The battery used to supply current to the microphone circuit in a telephonic transmitter.

Battery, Thermochemical. See GENERATOR, THERMOCHEMICAL ELECTRIC.

Battery-booster Set, a combination comprising a storage battery, *i.e.* an accumulator, in series with a reversible booster. On a lighting load, the booster is usually hand-regulated, taking the place of regulating cells. On a rapidly varying power load, the booster is usually automatic (see HIGHFIELD BOOSTER and ENTZ BOOSTER), and by adding its pressure in direct proportion as the battery pressure decreases, due to the rate at which it is discharging, maintains the pressure of the combination constant, and relieves the generating plant of the fluctuations of the load. The size of the generating plant necessary, is thus considerably reduced, as it need only be large enough to handle the average load instead of the maximum load, and can be worked at its highest efficiency. Thus the load on the generator remains steady, notwithstanding the heavy fluctuations in the line current. See also BOOSTER, and BATTERY, BUFFER.

Battery Cell. See ACCUMULATOR.

Battery-charging Booster. See BOOSTER.

Battery Cut-out, an automatic switch for disconnecting a battery of accumulators from a charging dynamo should the pressure of the latter fall below a predetermined value, or should the current become reversed. It is often arranged to also automatically close the battery switch so soon as the pressure of the charging dynamo has risen to a predetermined value.

Battery Gauge, a portable voltmeter for testing the condition of the cells of an accumulator.

Battery Insulator. See 'Accumulator Insulator' under INSULATOR.

Battery Meters and Battery-metering Systems.—When the charge and discharge of a battery are measured by amp hr or w hr meters, these are referred to as battery meters. Amp hr motor-meters should be preferably used, reading in amp hr. When w hr meters are employed, they are very often calibrated to register in amp hr, their pressure circuits being, as a rule, connected to a source of constant or approximately constant pressure, such as the lighting circuit. Two methods are in vogue—the one-meter battery system and the two-meter battery system. See METER, AMPERE HOUR, FOR BATTERY.

ONE-METER BATTERY SYSTEM.—In measuring the charge and discharge of a battery (*i.e.* of an accumulator), very often only one battery meter is used. It is permanently connected to the battery, so that, unless special devices be adopted, the record of the charge is destroyed on the discharge, the latter by a subsequent charge, and so on. The dials have therefore to be read after each charge and discharge. When an energy motor-meter is used for this purpose (Thomson type), the compensating coil must be removed, otherwise the field of the compounding coil would oppose the field of the main coils on the discharge, and cause the meter to under-register. In many battery meters, two distinct dials are used, the charges and discharges being continuously and separately integrated. The interchange between the meter and one or other of the two dials, is made by a mechanical device dependent upon the direction of flow of the current to or from the battery. Instead of using two dials, one large circular dial is often used, arranged so that the position of the pointer always indicates the exact amount of capacity available. The records are, of course, destroyed, as indicated above. Usually when the pointer stands at zero on the dial face, the battery is fully charged. The necessary difference between the charge and discharge is allowed for, either electrically or in the gearing.

TWO-METER BATTERY SYSTEM.—A very common method of separately measuring the charge and discharge of a battery, is to use two battery meters (preferably amp hr motor-meters). They are permanently connected in series with the battery in such a manner that the current traverses their main-current circuits in the reversed sense. By means of a mechanical device (ratchet and pawl), and in some cases, (oscillating type), dependent upon the principle of working of the meter, the one meter is only free to operate on the charge and the other on the discharge.

[H. G. S.]

Battery Plate. See ACCUMULATOR PLATE.

Battery Spear. See VOLTMETER.

Battery Switch. See SWITCH, ACCUMULATOR.

Battery Voltmeter. See VOLTMETER.

Baudot Type-printing Telegraphy. See under TELEGRAPH SYSTEMS.

Baur's Law for Electric Breaking Strength. See ELECTRIC BREAKING STRENGTH.

Bayonet Cap. See CAP OF INCANDESCENT LAMP.

Bayonet Holder. See LAMP HOLDERS.

Bdf, abbreviation for break-down factor (of induction motor) (which see).

Beacon Wire. See WIRE, BEACON.

Bearer Cable. See CATENARY SUSPENSION.

Bearers for Accumulator. See ACCUMULATOR, BEARERS FOR.

Bearing Friction in Dynamos and Motors.—Much attention has been devoted to bearing friction and much experimental data has been collected, but unfortunately in most cases the results are far from concordant.

In general we may say that the work energy transformed per min into heat, for cylindrical bearings, in m kg, is equal to

$$\frac{\mu W \pi D N}{100} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 1$$

where μ is the coefficient of friction, W the total load on the bearing in kg, N the speed in rpm, and D the diameter of the bearing in cm. The value of μ, however, is somewhat indefinite, varying with the intensity of pressure, the velocity of rubbing, and the method of lubrication. It is fairly safe to consider, in ring lubricated bearings, that the value of μ varies inversely as the intensity of the pressure, and nearly proportionately to the sq root of the velocity.

Hence we may write, for the friction resistance R, in kg,

$$R = \mu W = k \frac{\sqrt{v}}{p} \cdot W$$

where v is the velocity, p the intensity of pressure, and k a constant having an approximate value of 0·0176 when v is in m per min.

Now $p = \frac{W}{Dl}$ where l is the length of the journal in cm.

Hence in the above equation we have

$$R = kDl\sqrt{v} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 2$$

an equation which shows that the loss in bearing friction is independent of the load; a fact which has been repeatedly verified experimentally by Dettmar and others.

Now the total power lost in the bearing, is proportional to the 1·5 power of the velocity, from equations 1 and 2. Hence by reducing the diameter of the bearing, the frictional loss is considerably reduced; a limit, however, is imposed by the strength of the shaft. We may then proceed to reduce the length of the bearing again until the limit of intensity of pressure is reached, under which the oil film breaks down. This intensity varies with the velocity. At 150 m per min, the average velocity of journals in dynamos; it is 76 kg (Livingstone); while Goodman puts the limit for good white metal at 220 kg and plain gun metal at 90 kg. See also LOSS, FRICTION AND WINDAGE.

(Ref. 'Friction Losses in Dynamos', G. Dettmar in E.T.Z., vol. xx, pp. 380, 397, also vol. xx, p. 651, 1899; 'Some Notes on the Mechanical Design of Electrical Generators', R. Livingstone in Elec., vol. lvii, p. 687, 1906; 'Mechanics Applied to Engineering', Goodman; 'Elements of Machine Design', Unwin.)

Bearings, the gun-metal or cast-iron bush (lined with soft white metal) which is mounted in a pedestal or frame and so acts as a support for a shaft.

The type of bearing most commonly used to support the shafts of electrical machinery is shown in fig. 1, in which A is the shaft, B the gun-metal bush, and C the cast-iron pedestal which supports the whole and at the same time forms an oil reservoir. The rings D, turning round with the shaft, carry up a constant stream of oil, which passes along the bearing and out at the ends, falling

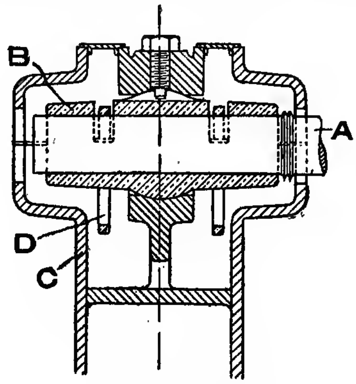


Fig. 1.—Plain Bearing

back into the reservoir. This bearing gives good results with ordinary speeds and loads.

FORCED LUBRICATION.—For the very high speeds at which turbo-generators are run, a different form of bearing is necessary; white metal is used instead of gun metal. The oil rings are omitted, and oil under pressure, is conveyed by a pipe to the bearing. After passing through the bearing the oil is drawn through a cooler, of somewhat similar construction to an ordinary condenser, and is then forced again through the bearing, being generally passed through a filter after being cooled. For the purpose of keeping up the flow of oil under pressure, a small force pump is used, driven by a small motor.

OUTBOARD BEARING. — In high-speed-engine generating sets, the dynamo or alternator is often directly attached to a coupling

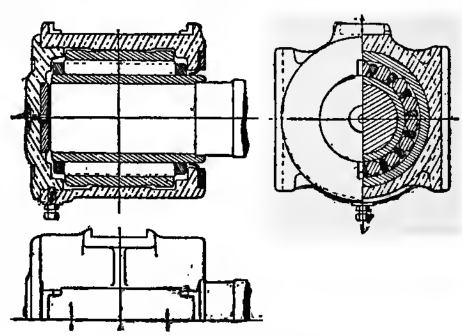


Fig. 2.—Roller Bearing for Axle

plate on the engine shaft, and the bearing in the engine frame also serves as one of the bearings of the dynamo. The separate bearing on the other side of the dynamo, usually of the pedestal type, is generally termed the outboard bearing.

ROLLER BEARINGS.—Roller bearings have from time to time been tried for electric machinery, but have so far met with little favour. They appear to be more suited for heavy loads and slow speeds. An example of an axle-box roller bearing is illustrated in fig. 2. A number of these are in successful use in electric tramway and electric railway work.

BALL BEARINGS.—The use of ball bearings for electric machinery is steadily increasing, some firms now making standard ranges of machines from $\frac{1}{4}$ up to 25 bhp fitted with bearings of this type.

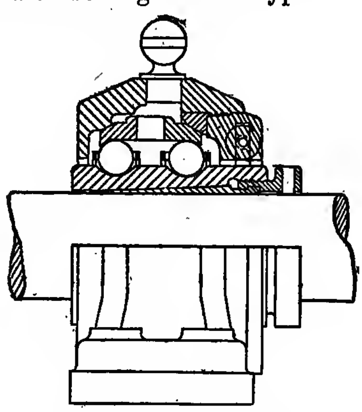


Fig. 3.—Horizontal Ball Bearing

They have been used with satisfactory results for autocar motors and crane motors, and for the vertical spindles of high-lift turbine pumps which run at very high speeds. An example of a ball bearing for a horizontal shaft is illustrated in fig. 3.

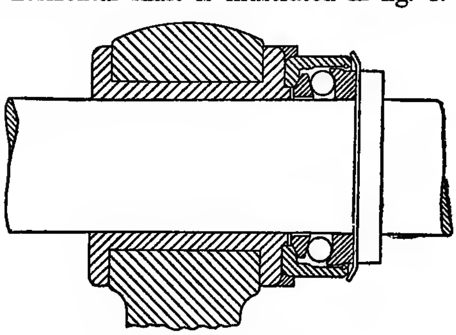


Fig. 4.—Ball Thrust Bearing

THRUST BEARING.—Where a shaft is subjected to end pressure, a thrust bearing is necessary to withstand this pressure. A form of thrust bearing largely used for the shafts of electric motors when driving by worm gear is shown in fig. 4. In the bearing illustrated, the thrust is taken by a circle of balls. In place of these, collars are sometimes turned on the shaft, and these fit into grooves turned in the gun-metal bearing bush.

FOOTSTEP BEARING. — In vertical shaft

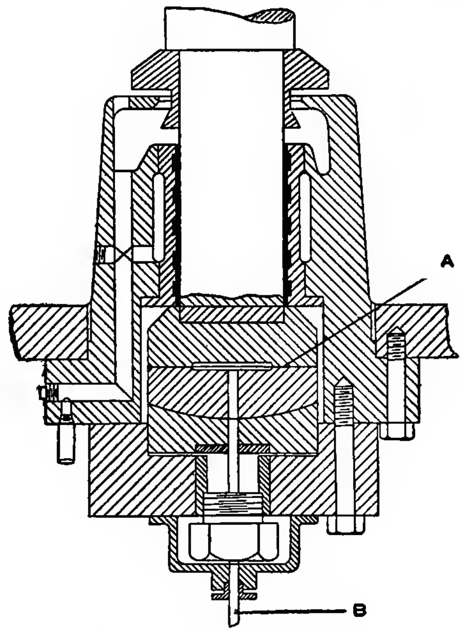


Fig. 5.—Footstep Bearing for Turbine

machines, in order to support the weight of the revolving member, a special bearing is usually provided at the base of the machine. In small machines this is often a ball bearing, but in larger sizes the weight would crush the balls, and so a film of water or oil is maintained between the bottom of the shaft and the bearing, by means of hydraulic pressure. Roller bearings, however, have

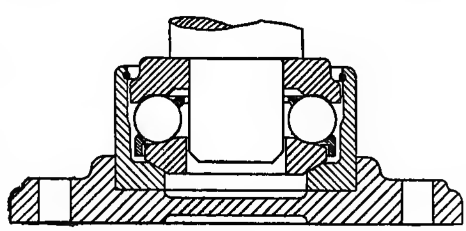


Fig. 6.—Ball Footstep Bearing

been successfully employed in large machines. To support the lower end of vertical shafts, such as the shafts of turbines, footstep bearings are used. A bearing of this type is illustrated in fig. 5. The pressure is taken at the surface A, to which oil is fed under pressure by the pipe B. The bearing metals are usually steel and gun metal. A ball footstep bearing is illustrated in fig. 6.

PEDESTAL BEARING, a bearing which is carried on a separate pedestal which is bolted down to a common bed plate with the generator or motor, or to a separate foundation plate. They are used mostly with large-sized machines, as with small machines it is more convenient and compact to have the bearings in end shields which are bolted to the sides of the frame of the machine.

SELF-ALIGNING BEARING, a bearing which sets itself to any curvature or deflection of the shaft. To do this, the bearing-bush seating in the pedestal, is made a portion of a sphere, so that the bearing bush can rock in any direction without changing the area of its seating surface. In some large bearings, the bush is split in two, each unit bush being mounted in a spherical seating. This last arrangement allows for the bow shape assumed by a shaft loaded on each side of the bearing.

LUBRICANTS FOR BEARINGS. — For the lubrication of the bearings of electrical machinery, mineral oils are used almost exclusively, as they maintain their fluidity under exposure to the air for a longer time than animal or vegetable oils, and are practically free from any tendency to cause corrosion of the metallic surfaces with which they are brought in contact. The most important characteristic of a lubricating oil is its viscosity, which, at the temperature at which the bearing works, should be sufficient to prevent the oil from being squeezed out by the pressure between the surfaces.

If the oil is too thick, it clogs the bearing and makes the frictional loss greater than is necessary, while if it is too thin, it is squeezed out, with the result that the bearing runs hot. Thus for any given bearing, the viscosity should be as low as possible consistent with the maintenance of a continuous film of oil between the surfaces of the metals.

It is sometimes claimed that roller bearings and ball bearings work better without oil, but that the rollers, or balls, and races should be covered with a slight film of vaseline to prevent rust. The recommendation of certain manufacturers of ball bearings is, however, that the bearings should be filled with grease or oil. [C. W. H.]

Beaumé Hydrometer Scale. See HYDROMETER SCALES.

Beck Hydrometer Scale. See HYDROMETER SCALES.

Becquerel's Laws of Thermoelectricity.—(1) If the junctions of circuit of two metals be kept at temperatures t_1 and t_2, the emf generated is the same as the sum of the emf of two circuits of the same metals working at temperatures t_1, θ, and θ, t_2 where θ is an intermediate temperature. (2) The interposition of a number of different metals in a circuit originally containing two only in series, makes no difference in the emf if all the junctions be at one temperature. See also THERMOELECTRICITY.

Bed Blocks, machined blocks fixed on the concrete foundations and forming a levelled base on which to rest the feet of an alternator or other dynamo-electric machine. See FOUNDATION PLATES.

Bedplate, an inverted trough-shaped casting which serves as a common foundation for the various frames and bearings of a motor, generator, a motor-generator set, an engine-driven set, or any combination of coupled machines. In small single motors, the bedplate is nowadays usually dispensed with, as the bearings are frequently carried in the *end shields.* Also with large sets, where a bedplate would be too cumbersome, the generator is mounted upon separate *foundation plates* (which see).

Behrend's Formula. — In Behrend's treatise, 'The Induction Motor', the author proposes the following formula for σ, the circle (or dispersion) coefficient:—

$$\sigma = \frac{C\,\Delta}{\tau}$$

where C is a factor varying between 10 and 15,
Δ is the radial depth of the air-gap in cm, and
τ is the pole-pitch at the air-gap in cm.

See 'Dispersion Coefficient' under DISPERSION, MAGNETIC.

Behrend's Split-field Method.—This is a modification of Mordey's split armature test for alternators (see TESTS, SPLIT ARMATURE) introduced by Behrend for the purpose of overcoming the serious magnetic unbalancing produced by Mordey's method of test. Instead of exciting the field in the ordinary manner, the field circuit is divided into two unequal sections, and each section is excited separately by an independently controlled current. In this way the magnetising action of the motor coils of the armature is compensated for by a corresponding reduction in the exciting current for that portion of the field, and the demagnetising action of the generator coils are counteracted by an increase of the excitation of the other portion of the field. By this means the magnetic balance of the machine may be maintained, and vibration of the machine may be materially reduced. Behrend's method is described in the 'Elec. World and Engineer', vol. xlii, Oct. 31 and Nov. 17, 1903. (Ref. 'Alternating Currents', Hay, p. 173.)

Behr Monorail System. See MONORAIL ELECTRIC RAILWAY.

Bell, Electric, a bell rung by a hammer actuated by electricity. The mechanism is a kind of reciprocating motor in which the force is applied intermittently in one direction, the reverse movement being due to a spring. The circuit of a small electromagnet is completed through the spring supporting the hammer and through a contact fixed to the base board. This contact is closed when not in action. When the circuit is closed by the push button the current from the battery energises the magnet, which then attracts the armature (piece of soft iron) attached to the stem of the hammer; this motion breaks the circuit at the spring, the current stops, and the hammer flies back again and remakes the circuit. The process then repeats itself, and at each repetition, a stroke is given to the bell (or gong). Bells are also arranged to give only a single stroke each time the button is pushed.

Bell, Magneto.—The electric generator, with permanent field magnets, used in ringing a telephone bell is called a *magneto* or *magneto-electric machine*. It is usually constructed as a simple type of alternator.

Bell, Relay, a relay which makes the local bell circuit when the current from the distant station or instrument passes through its magnet windings.

Bell's Photophone. See WIRELESS TELEPHONY.

Belt Conveyor. See COAL CONVEYORS.

Belt Gearing. See GEARING FOR ELECTRIC MOTORS.

Belt Leakage. See DISPERSION COEFFICIENT.

Belt Transmission Dynamometers. See DYNAMOMETER, TRANSMISSION.

Benardo's System of Electric Welding. See WELDING, ELECTRIC.

Bent Antennæ. See ANTENNÆ.

Benzene, an extremely volatile liquid, having a chemical composition indicated by the formula C_6H_6. It is the characteristic constituent of coal tar, and is of a more volatile nature than coal-tar naphtha. It is a good solvent for indiarubber, resins, and pitches. See also NAPHTHA.

Benzine, a refined distillation product of petroleum. It is a water-white limpid liquid, completely evaporating at atmospheric temperatures, though not quite so rapidly as benzoline. It has a specific gravity of about 0·74 to 0·78, and is extensively used for thinning baking insulating varnishes. See also PETROLEUM AND SHALE SOLVENTS.

Benzolene (alternative spelling, **Benzoline**). See NAPHTHA.

Berlin-Zossen Tests. See TESTS, BERLIN-ZOSSEN.

Berrite, the trade name of an impregnating material with good insulating properties, which the manufacturers claim are unaffected by high temperature. Berrite is also employed as impregnating material in a line of so-called Berrite cloths and fabrics.

Berry Transformer. See TRANSFORMER, BERRY.

Berry Transformer Switch. See SWITCH, BERRY TRANSFORMER.

Bevelled Pole Shoe. See POLE SHOE.

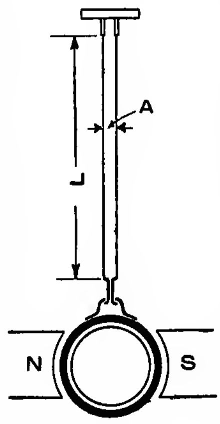
B-H Curves. See MAGNETISATION, CURVE OF; HYSTERESIS LOOP.

Bhp, the preferable abbreviation for brake horse power. See HORSE POWER.

Bi, the chemical symbol for bismuth (which see).

Bichromate Battery. See BATTERY, PRIMARY.

Bifilar Suspension. — Two wires or strips of metal of equal length, spaced at equal distances apart at both ends, are used for supporting a galvanometer movement or other swinging system. A bifilar suspension is shown in the figure. Both strips tend to lie in the same plane, and if the movement is twisted through some angle, θ, the force required to balance the controlling force is equal to $\frac{1}{4}\frac{A^2}{L} w \sin\theta$, where A = distance between the supports, L is their length, and w is the weight of the movement. This expression neglects the effect of torsion in the supports themselves, and for small angles, such as the deflection of a mirror galvanometer, the force may be considered as simply proportional to the angle of deflection, θ. The method is commonly employed in a 'moving coil' galvanometer, and the supports carry the current into and out of the coil.



Bifilar Suspension

Bifurcating Box. See Box, Bifurcating.

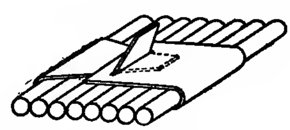
Bimetallic Wire. See Wire, Bimetallic.

Binding Bands.—The conductors of a cc armature are usually wound in open slots, and are kept in place against the action of centrifugal force either by longitudinal wedges, or by tinned steel wire or phosphor-bronze wire, which is wound around the armature and clipped and soldered. These bands should not exceed 12 mm in width, as otherwise eddy currents may be generated in the band, which may melt the solder and allow the bands to fly apart.

Binding Wire.—Steel wire is the more usual material for binding bands, and a good wire should be able to work at 10 kg per sq mm with a factor of safety of from 7 to 10. In describing Messrs. Parsons' latest turbo-dynamos, Messrs. Stoney and Law, in a paper read before the I.E.E. on April 2, 1908, made the following comparison between phosphor-bronze and steel-wire materials for binding bands:—

'The conductors are held to the core by binding wire made of steel piano wire, a material which long experience has shown to combine the qualities of reliability and high tensile strength, which render it immensely superior to such material as phosphor bronze. Its magnetic properties are its one defect, but careful tests have shown that these are relatively of minor importance. A series of experiments made about 1887 showed that in small turbo-dynamos of 12 to 16 kw, running at speeds of from 8000 to 9000 rpm, giving periodicities as high as 130 to 150, the saving in power obtained by using phosphor bronze instead of steel wire amounted to only about 2 per cent, and a further series of experiments conducted in 1904 on two 150 kw armatures at 3600 rpm showed a saving in power of less than 0·30 per cent by using phosphor-bronze wire, and it is still less in larger armatures. Against this saving must be set the fact that phosphor bronze has much lower tensile strength, and therefore a larger quantity is required. Also bronze wire is liable to have occasional soft spots of weaker material, which is a vital defect, and it is a matter of experience that steel binding wire, when properly applied, is extremely reliable.'

Clips for Binding Bands.—In order to secure the wire, the various turns, besides being soldered to one another around the armature, are usually anchored at intervals in thin tinned sheet-iron clips, taking the form indicated in the sketch. The flap is bent down, and the whole construction is liberally served with solder, and so forms an efficient anchor, especially for the start and finish of the wire in the band. [H. W. T.]


Clips for Binding Bands

Binding Post or Binding Screw, a terminal device to which wires, single or stranded, can be attached by screwing a cap down a threaded post (or by equivalent means), and so clamping the wires in position.

Bi-phase. Synonymous with Two-phase and Quarter-phase. See Alternating Current.

Bipolar, having two poles.

Bipolar Armature. See Armature.

Bipolar Dynamo, a dynamo-electric generator with two poles. See Generator.

Bipolar type, a type of dynamo field magnet machine having two poles only—one north and one south. See fig. on p. 51.

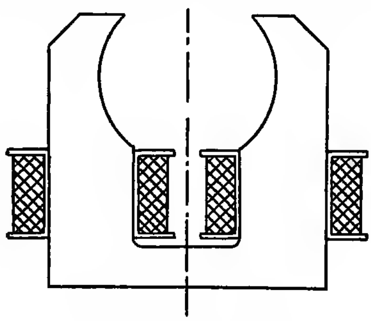
Bipolar Winding. See Winding, Bipolar.

Birmingham Wire Gauge (abbreviation, BWG). See Wire Gauge.

Bismuth (chemical symbol, Bi), a metal whose specific resistance, as determined by Matthiesen, is 130 microhms per cu cm at 0° C. Its resistance is increased by 0·35 of 1 per cent per degree Centigrade increase in temperature. Its resistance is also a function of the density of the magnetic field in which it lies. Its specific gravity is 9·8.

Bismuth Spiral Density Tester. See Tester, Bismuth Spiral Density.

Bitumen.—The term *bitumen* has been applied to a series of hydrocarbon com-



Bipolar Type of Field Magnet

pounds of the olefiant and paraffin series. They are plastic solids of varying compositions, but when mixed with other ingredients, are capable of vulcanisation. The use of bitumen for insulating purposes was introduced by the late Mr. W. O. Callender, who in 1879 patented an insulating material in which it formed the chief ingredient. Like rubber, the ingredients with which it is mixed, greatly vary its properties, but it is extensively used as a dielectric for 'vulcanised bitumen cables'. It is water repellent, has high dielectric strength and insulation resistance, and although it oxidises on the surface, these properties remain permanent. It lacks mechanical strength, but this is overcome by the use of a jute or armoured covering. Another disadvantage is its low softening temperature, and a vulcanised bitumen cable should not be run at a higher current density than some 120 amp per sq. cm. Under some conditions, this may be exceeded, but may be taken as a safe working limit. The use of vulcanised bitumen alone as a dielectric is restricted to medium pressures only. For cables that must be laid in damp situations, the water-repellent and permanent properties of bitumen, render it superior to either paper or rubber.

Bitumen, in its raw state, is chemically inert, and seems unaffected by exposure to climatic conditions. This has led to its adoption in the manufacture of conduits, and as a filling for cable troughs and joint boxes. It is also used to some extent in the manufacture of impregnating compounds. See also Trinidad Bitumen; 'Vulcanized Bitumen' under Cable, Underground. [H. D. S.]

Bitumened Paper Tubing. See Conduit, Interior.

Bituminous Conduit. See Conduit, Underground.

Black Body.—A 'black body', from the scientific point of view, is a body which is capable of absorbing all the radiant energy striking it. According to Kirchoff's law, such a body must also be capable of radiating all varieties of energy, and can therefore never be an efficient light-producer, when heated to incandescence.

A truly black body is only with difficulty prepared in practice (see Lummer and Wien, Wied. Ann. Bd. 56, p. 451, 1895. Most incandescent sources of light, such as the carbon-filament glow lamp, and most flame sources approximate to such a body.

Black Fibre. See Fibre.

Blackening of Incandescent Lamps. See 'Disintegration of Filaments' under Filaments.

Blake's Telephone Transmitter. See Transmitter.

Blanking Die. See Die, Blanking.

Blasting, Discharger in. See Discharger.

Blasting by Electricity.—This term refers to blasting in which the explosive charge is fired electrically. The fuse consists of a small case containing some detonator such as fulminate of mercury, in which are placed two wires a short distance apart. These wires are led to a high-pressure magneto-generator, usually worked by hand, which sets up a spark between the wires in the detonator, thus igniting it.

In another type of fuse, a very small wire is laid in the detonator, and from it, wires are led to a battery, the current from which is sufficient to make the small wire white-hot, so causing ignition.

Bleach, Electrolytic. See Electrolytic Bleach.

Bleaching Agent in Impregnated Cloths, Defects caused by Presence of.—The presence of any bleaching agent in an impregnated cloth will prevent the impregnating material from thoroughly penetrating, and may result finally in rotting of the fabric.

Bleeding.—At the cut ends of paper-covered cables there is a tendency for the material with which the paper is impregnated to ooze out. This occurrence is termed bleeding. Owing to this tendency large paper-covered cables should preferably not be employed for vertical runs.

Block Section. See BLOCK SYSTEM FOR RAILWAYS.

Block System for Railways, a system for the regulation of traffic on railways. A single line of railway, or the 'up' and 'down' tracks of a double line, is equivalent to a lane so narrow that any one vehicle occupies its full width, and passing, whether in the same or in opposite directions, is absolutely impossible. In mathematical language, a train has only two freedoms (forward and backward), while a carriage on an ordinary road has four (forward, backward, right, and left) out of the total six possible. Hence the necessity for a system of external and local control which is designed to prevent two trains from coming to the same portion of the line at one time, *i.e.* to prevent collision. The block system, which is employed on all railways where trains are frequent, consists in dividing the line into sections, varying in Great Britain from a fraction of a mile up to 18 or 20 miles in length. On each of these sections, only one train is allowed at a time. For steam-drawn traffic, the blocking is merely by signal. The signal at the end of the block (or section) is called the home signal. Its indications must be strictly obeyed, *i.e.* the train must stop if the home signal is at 'danger'. The indications of the home signal are repeated by another signal some hundreds of yards down the line in the direction from which the trains are travelling. This is called the 'distant' signal, and is merely a warning to the driver, of the condition of the home signal, in order that he may not overrun the home signal; it does not, in itself, constitute a block. A starting signal is also provided at the fore end of each station in many cases. For electric railways, the blocking may be either by signal or purely automatic, *i.e.* by the action of a passing train cutting off the current from the block behind.

AUTOMATIC BLOCK SYSTEM, an arrangement of electrical circuits such that every train indicates its presence by blocking, by means of signals, the section on which it is. In electric railways, the principle is sometimes extended so that the current is actually cut off as each train leaves a section, and only again connected when the train passes into the next section. There is thus always a dead section behind every train. In partially automatic systems it is impossible for the signalman to release a signal or change points until he has received an electrical signal from the next block. Where traffic is heavy, block sections are short as a rule, in order to permit of trains following at small intervals of time, since the smallest permissible interval is equal to the time taken by a train to pass over the section from end to end.

The term is frequently applied to a system of traffic regulation which is *only partially* automatic, since it requires to be operated by signalmen. It is usually automatic as regards points, in that the corresponding signals cannot be moved until the points have been set properly (interlocking signals). On single lines, the tablet, without which no train is allowed to proceed on to a section, is released only by an electrical device operated from the signal box at the far end of the section. See also SIGNALLING SYSTEMS.

[J. E-M.]

Blondel Hysteresimeter. — This instrument may be regarded as being similar to the Grassôt fluxmeter, with the exception that the coil is fixed and the magnet is suspended within it. In order to eliminate air-friction, and torsion, the magnet is suspended in vacuum by a quartz fibre suspension.

Blondel Oscillograph. See OSCILLOGRAPH.

Blow. See BLOWING A FUSE.

Blower Motor, in transformer installations, a motor which drives a fan or an air compressor for the purpose of blowing air through the transformer cases to cool them. Blowers are, of course, almost always driven by motors, which would obviously be termed *blower motors*, but the term as at first defined has the significance thus indicated.

Blowing a Fuse, melting a fuse by a sufficiently heavy current. Sometimes the expression is used in the limited sense of a rupture of a fuse by the great current rush due to a short circuit, as opposed to a rupture due to a current only slightly above the carrying capacity of the fuse, in which case the fuse is said to 'melt'. (Ref. 'Central Station Electricity Supply', Gay and Yeaman.)

['*Blow* (verb). When a fuse melts it is sometimes said to 'blow', a term suggested, probably, from the result of the melting of a fusible plug in a steam boiler. The same expression is sometimes applied to the automatic opening of a circuit breaker.'—I.E.C.]

Blowing Point of Fuse. See FUSE; BLOWING A FUSE.

Blown Linseed Oil. See LINSEED OIL.

Blow-out Solenoid. See SOLENOID, BLOW-OUT.

Board, a frequently employed abbreviation for switchboard (which see).

Board of Trade.—

['*Board of Trade,* a British Government Department charged with the administration of, *inter alia,* the Electric Lighting and Power Acts, Railway and Tramway Acts, and of regulations made thereunder for the safety of the public, &c.'—I.E.C.]

Board of Trade Ohm. See OHM.

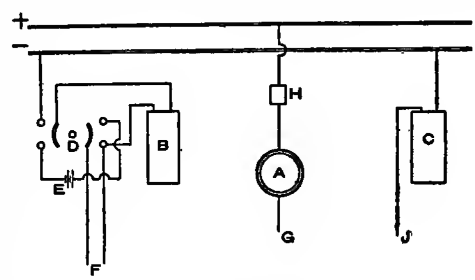
Board of Trade Panel, a panel added to switchboards in traction generating stations or sub-stations, and fitted with the apparatus necessary to carry out the tests required by the Board of Trade in connection with electric traction systems in this country.

The requirements of the Board of Trade are: 1. That the return circuit when uninsulated—*e.g.* the rails—shall be in connection with two separate earths not less than 20 m apart, and so arranged that an emf not exceding 4 volts shall suffice to produce a current of at least 2 amp from one earth connection to the other through earth. A test of this is to be made once a month, and an armature reading from 0 to 10 amp, a primary battery of two secondary cells, and a double-pole throw-over switch, are generally provided on the panel to enable the test to be carried out.

2. That, during working, the current passing from earth through the earth connections to the generators or bus-bars, shall not exceed 2 amp per mile of single line, or 5 per cent of the total current output of the station. A recording ammeter is provided on the panel, to test compliance with this requirement, often with an automatic switch to short-circuit the ammeter and so protect it in the event of a heavy earth current flowing.

3. That a continuous record shall be kept of the difference of potential between the distant ends of the rails and the rails nearest to the generating station, and that the difference must not exceed 7 volts. A recording voltmeter for each route is mounted on the panel, and connected to a pilot wire running to the distant end; sometimes a single recording voltmeter is used, with a multi-contact switch to connect it to any one of a number of pilot circuits.

4. That the insulation of the positive side of the system shall be such that the leakage current shall not exceed $\frac{1}{100}$ amp per mile of tramway when the line is fully charged at the working potential; this test to be made daily, before and after the running of the cars. An ammeter with two scales,



Board of Trade Panel

A, Ammeter. B, Recording ammeter. C, Recording voltmeter. D, Change-over switch. E, Battery. F, To earth plates. G, To generator. H, Fuse. J, To test-point of rail.

one reading 0·001 to 0·05 amp and the other 0·01 to 0·5 amp, is generally provided for the test, together with a switch for each scale, and a multicontact switch to connect to any desired overhead circuit. [F. W.]

A typical panel is shown in the figure.

(Ref. 'Electrical Traction', Wilson and Lydall; and 'Electricity Control', Andrews.)

Board of Trade Regulations, rules laid down by the Board of Trade affecting electric supply, traction, and lighting in all their branches. The restrictions imposed refer to working pressures, protective devices, leakage currents, variation of supply pressure, &c. &c. (See GUARD WIRE; CONDUCTORS, OVERHEAD; PRESSURE.)

Board of Trade Standards denotes usually the standard instruments and resistances used at the B.O.T. laboratory to check other instruments when the accuracy of the latter is in question.

Board of Trade Tests. See BOARD OF TRADE PANEL.

Board of Trade Unit denotes a unit of electrical energy equal to 1000 w hr or

1 kw hr. This unit is widely used in considering the quantity of electrical energy generated by electrical plants. It is desirable that it should be called a kelvin, and this should be internationally authorized. There appears good reason to believe that the kelvin will ultimately be accepted as the practical engineering and commercial unit of energy, whether manifested as electricity or in other forms. The kelvin is equal to 367 ton meters. (See KELVIN.) One Board of Trade Unit (*i.e.* one kelvin) is equal to 3,600,000 joules.

['*Board of Trade Unit*, 1 kw hr. The expression 'Unit' is officially used, and not the expression 'Board of Trade Unit'.'—I.E.C.]

Bobbin, a coil of insulated conductor such as is used on field magnets. It is thus named from its resemblance to the 'bobbins' commonly used in cotton manufacture, though in modern dynamo electric machinery the resemblance has become very obscure. As applied to the coils of little electromagnets, however, the term is fairly appropriate.

Bobbin, Winding, a former for a coil of small insulated wire, which, when wound, somewhat resembles an ordinary bobbin of cotton (*e.g.* small shunt-field coils, and coils of small electromagnets).

Bogie Truck. See TRUCK.

Boiled Linseed Oil. See BOILED OIL; LINSEED OIL.

Boiled Oil, linseed oil (which see) which has been subjected to a temperature of at least 100° C.

Bolometer, an instrument comprising a very fine short wire, the resistance of which alters with change of temperature, and which forms one arm of a Wheatstone bridge. The bolometer is used in measuring feeble heat radiation, such as that of the moon, to which radiation the wire is exposed; also as thermal detector of minute currents received in wireless telegraphy, by connecting the ends to aerial and earth conductors. The wire should be of material having a high temperature coefficient, and should be coated with a black material so as to be efficient in absorbing the radiant energy to which it is exposed. The radiant energy is absorbed by the black surface, and, being converted into heat, raises the temperature of the resistance. The subsequent alteration in resistance is then utilised to measure the energy of the radiation causing this change. See BARRETTER. (Ref. 'Trans. Am. I.E.E.', 13, 1906, p. 137.)

['*Bolometer*, an instrument in which the radiant energy to be measured, causes an alteration of the resistance of a fine wire strip or filament.'—I.E.C.]

Bond, a metallic connection between consecutive or adjoining rails or other conductors forming part of an electric circuit, such as the track rails of a tramway or railway, the third and fourth rails of a railway, or the conductor rails of an underground conduit tramway.

['*Bond* (for tramway and railway lines), a connector, usually of copper, used for electrically connecting the rails to each other or to a return conductor, in order to ensure good conductivity. (Verb: to bond.).'—I. E. C.]

Several types of bond are in use, mostly made of copper.

The CHICAGO RAIL BOND consists of a copper rod with swelled ends, which are inserted into holes freshly drilled or reamed in the webs of the rails. Steel drift pins are then driven into holes in the ends of the bond, expanding the copper into intimate contact with the substance of the rails.

The CHICAGO CROWN BOND is somewhat similar, but the solid terminals are usually connected with stranded copper cable, and the drift pins are driven from the side of the rail on which the bond is applied. The Chicago Rail Bond and the Chicago Crown Bond are of a type sometimes designated as *Steel Core Bonds.*

In the COLUMBIA BOND the swelled ends of the bond are conical and solid, and tapered thimbles are driven in between them and the surface of the holes in the rails.

The NEPTUNE BOND is like the Crown Bond; the ATKINSON CAST BOND also differs from these only in detail.

The EXPANDED TERMINAL BOND has solid ends, which are joined by flexible strands, and are expanded by pressure into the holes, without pins or thimbles. Most of these bonds are made in forms suitable for use either under the fishplates, under the foot of the rail, or outside the fishplate. Bonds secured to the webs of the rails are termed *Web Bonds.* Bonds located under the foot of the rail are termed *Foot Bonds.* Bonds located between the fishplate and the web of the rail are termed *Protected Rail Bonds.* An important advantage of protected rail bonds is that they cannot be easily stolen.

The EDISON-BROWN PLASTIC RAIL BOND consists of a plastic metallic compound which is applied between the web of the rail and the fishplate, thus utilising the conductance of the latter. It is held in place by a cork case.

The EDISON-BROWN PLASTIC COPPER BOND is a short copper bond provided with two embossed cups, which are applied to the webs of the rails, close to their ends. The surfaces of the rails and cups are covered with the Edison-Brown plastic alloy to ensure good contact, and stout steel springs, resting inside the cups, are forcibly compressed by the fishplate when the latter is bolted up, for the same purpose.

The SEMI-PLASTIC PLUG RAIL BOND is applied to the head of the rail or the bottom of the groove; in either case, a hole is drilled through the rail into the fishplate, amalgamated, and filled with a copper plug, thus connecting the rails through the fishplates.

WELDED RAIL BONDS are copper bonds electrically welded to the side of the railhead.

SOLDERED RAIL BONDS (Shawmut and Thomas) are copper bonds which are soldered to the side of the web or head of the rail. See also WELDED RAIL JOINTS; RETURN CIRCUIT IN ELECTRIC TRACTION.

[A. H. A.]

Bond Holes, holes drilled in the web or foot of the rail, and in which the heads of the bonds are secured. See BOND; BONDING RAIL.

Bond Tester, a portable instrument used for the purpose of ascertaining the resistance and condition of bonded rail joints, as compared with the resistance of an equivalent length of the rail.

Bonding Rail, connecting together the successive rails of the track of an electric tramway or railway, in order to provide a metallically continuous *return circuit* of low electrical *resistance* from the cars or trains to the power house or substation. See BOND; WELDED RAIL JOINTS.

RESISTANCE OF RAIL BONDING.—The resistance of rail bonding is the excess of resistance of a bonded line of rails over that of a continuous rail of the same material, cross section, and length over all.

SINGLE BONDING.—Only a single bond is employed to connect successive rails. This is often considered sufficient for suburban roads where the service is very light, and where the instantaneous rushes of current do not exceed, say, 700 amp. But where single bonding is employed, it is the more important that the rails should be liberally cross bonded.

DOUBLE BONDING.—At first sight it would appear that additional security would be obtained by employing two independent bonds to connect successive rails. This is the case if both sets of bonds are systematically inspected and maintained in good condition.

CROSS BONDING.—The two running rails should be frequently connected by long bonds. This is termed *cross bonding.*

Booster.—In general, a booster is a machine which adds to an emf derived from another source.

['*Booster,* a dynamo, alternator, or transformer, interposed in a circuit for the purpose of increasing or decreasing the emf acting in the circuit.'—I. E. C.]

[In paragraph 13 of the 1907 Standardisation Rules of the A.I.E.E. a booster is defined as 'A machine inserted in series in a circuit, to change its voltage. It may be driven by an electric motor (in which case it is termed a *motor-booster*) or otherwise.']

For example, if a storage battery (*i.e.* an accumulator) is used in conjunction with one or more dynamos to supply current to an electric-light installation, the battery cannot be charged from the machines which are feeding the lamps, because it requires a pressure some 40 per cent higher than the latter to complete the charge. A small dynamo is therefore connected in series with the generators and the battery, acting in conjunction with the former, to provide the necessary emf. Such a dynamo is called a *Battery-charging Booster.* Thus a battery-charging booster (sometimes more briefly designated a *Charging Booster*) is a dynamo for raising the pressure of a constant potential circuit for the purpose of charging a battery of accumulators. It may consist of a single armature with a double winding, a motor and dynamo coupled together on one bedplate, or a separate small dynamo, either belt-driven or arranged on an extension of the armature shaft of the main generator.

Similarly a booster may be inserted in series with a long feeder, to compensate for the drop of pressure in the feeder when heavily loaded. When the feeder is connected to the track of an electric tramway with rail return, with the object of maintaining the rails at the end of the feeder at the same potential as the earth, the booster is called a *Sucking Booster* or *Negative Booster.* For cc systems the boosters are usually dynamos, driven by any convenient means,; for ac, transformers are used. The field magnets of cc boosters may be either separately excited or series-wound. A booster which is designed to compensate for the variation of pressure of a storage battery when charged and discharged, alternately assisting and opposing the main generator, is called a REVERSIBLE BOOSTER (see BOOSTER, REVERSIBLE), and may consist of a combination of one or more machines, as in the HIGHFIELD BOOSTER (see under BOOSTER, REVERSIBLE), or it may, as in the Entz Booster, consist of a single machine with the field automatically regulated by an electromagnetic device (see under BOOSTER, REVERSIBLE). See also BATTERY BOOSTER SET; BOOSTER, REVERSIBLE; and MILKING BOOSTER.

Booster, Milking. See MILKING BOOSTER.

Booster, Motor. See BOOSTER.

Booster, Reversible, a machine (which can be either automatic, or controlled by hand) to both compensate for the drop in pressure of a battery on discharge and to raise the pressure of a constant potential circuit for the purpose of charging a battery.

SEMI-AUTOMATIC REVERSIBLE BOOSTER, a machine for running in series with a battery to deal with a varying load, but of which the pressure does not fall below the output of the generator; that is, the fluctuations are not so violent as to require the machine to reverse, or reverse within small limits only, as the machine is designed for hand reversal. It dispenses with end cells in the battery, enables the cells to be charged from the bus-bars, and takes care of moderate fluctuations.

DIFFERENTIAL BOOSTER, a type of reversible booster used in conjunction with a battery of accumulators, in which a series coil, energised from the main circuit, tends to discharge the battery, and a shunt coil, excited from the battery, tends to charge the cells. These two coils are opposed to one another, and the difference in their respective strengths represents the net ats available for boosting. In order to produce more quick reversal, additional compound coils are sometimes added.

TURNBULL-McLEOD AUTOMATIC REVERSIBLE BOOSTER.—This is also known under the name of the *Lancashire Automatic Reversible Booster.* It is the invention of Turnbull and McLeod, and is built by the Lancashire Dynamo & Motor Company. Fig. 1 gives a diagram of connections. The field magnets are provided with four coils, A, B, C, and D. A is connected across the terminals of the booster, and provides an excitation proportional to the difference in pressure between the bus-bars and the battery. Coil B is a shunt across the bus-bars, and C is a series coil carrying the main current. Coil D is in series with the booster, and serves to compensate for booster armature reaction and drop. A number of rheostats are provided for adjusting and controlling the various circuits. Certain variations in these

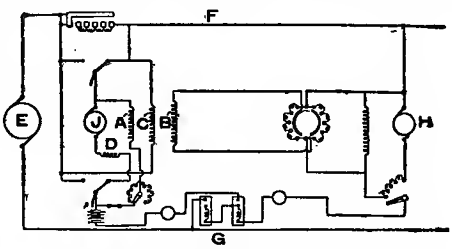


Fig. 1.—Turnbull-McLeod Automatic Reversible Booster

E, Main generator. F, − Main. G, + Main. H, Motor. J, Booster.

adjustments are occasionally desirable, according to the condition of the battery. (Ref. Turnbull, Journ.I.E.E., vol. xxxvi, p. 591.)

ENTZ BOOSTER, a type of reversible booster for working in series with a battery, on a rapidly varying load. Its operation is automatically controlled by a carbon regulator, consisting of not less than four piles of carbon disks, which are connected in the field-magnet circuit of the exciter in a manner similar to that of a Wheatstone Bridge. The total output of the generator is carried by the solenoid of the regulator, the core of which is attached to a lever, on the other end of which is an adjustable spring. Slight variations in the load on the generator cause changes in pressure on the carbon piles resulting in wide variations in their contact resistance, thus affecting the field excitation of the booster. Perfect control of the generator load is thus obtained, with consequent steadiness of the bus-bar pressure, notwithstanding the violent fluctuations of the line load. Considerable economies may in some cases be thereby effected, both in the first cost of steam plant necessary to handle a given load, and in running costs, owing to the steady load.

In fig. 2 is shown a diagram of connections

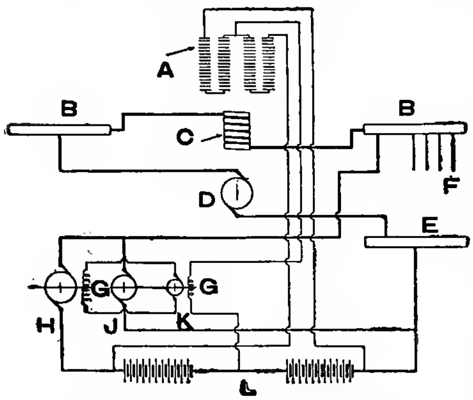


Fig. 2.—Diagram of Connections for Entz Booster

A, Carbon piles. B, Bus. C, Actuating coil. D, Main generator. E, – Bus. F, Feeders. G, Shunt coil. H, Booster. J, Motor. K, Exciter. L, Battery.

of the Entz Booster, and its carbon regulator is shown on the plate facing page 58.

HIGHFIELD REVERSIBLE BOOSTER.—Three machines—motor, booster, and exciter—coupled together on one bedplate, and arranged to automatically correct the varia-

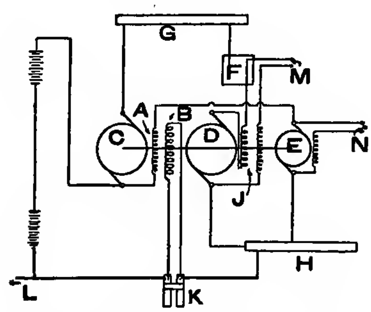


Fig. 3.—Diagram of Connections for Highfield Reversible Booster

A, Shunt winding. B, Series winding. C, Booster. D, Motor. E, Exciter. F, Motor starter. G, Positive Bus-bar. H, Negative. J, Differential coil for constant speed. K, Diverter. L, Rail Return. M, To rheostat. N, To rheostat.

tions in pressure at the terminals of a battery (*i.e.* of an accumulator) when working on a rapidly varying load, and thus maintain a constant pressure across the terminals of the combined booster-battery plant. The principle of its operation is that of balanced pressures, the emf of the exciter being balanced against that of the battery. The booster and battery maintain a constant load on the generating plant, and, if placed in a substation at the end of a feeder, keep the current flowing in the feeder, constant within a very small percentage; the amount of copper need thus be sufficient only for the average load instead of for the maximum load, resulting in considerable saving in capital expenditure.

In fig 3 is shown a diagram of the connections of a Highfield Booster. [F. C.]

Booster Set for Accumulator. See BATTERY-BOOSTER SET.

Booster Transformer. See TRANSFORMER, BOOSTER.

Bore of Armature, an expression used in connection with alternators and induction motors with external stationary armatures, meaning the inside diameter of the punchings, or the diameter of the punchings at their active face, *i.e.* at the gap.

Bore of Field, in a cc machine, the diameter to which the inside of the pole shoes are bored.

B.O.T. Ohm, abbreviation for Board of Trade Ohm. See OHM.

B.O.T.U., occasionally used instead of BTU for Board of Trade Unit (which see).

Boucherot's Methods of Starting Induction Motors. See STARTING OF MOTORS.

Bougie Decimale. See 'Violle Standard of Light' under STANDARD OF LIGHT.

Bougier Photometer. See PHOTOMETER, BOUGIER.

Bow Collector. See TROLLEY.

Bowstring Suspension. See SUSPENSION, TROLLEY-WIRE.

Bow-type Trolley. See TROLLEY.

Box, Bifurcating, a type of Dividing Box. See BOX, DIVIDING.

['A box containing the joints between a two-core and two single-core cables.'—I. E. C.]

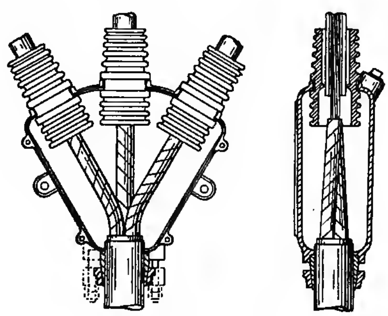
Box, Brush. See BRUSH HOLDER.

Box, Cable, a box into which cables are led to be jointed together. (Ref. 'Central Station Electricity Supply', Gay and Yeaman; 'Distribution of Electrical Energy', J. F. C. Snell.

Box, Contact, in surface-contact traction, a box buried beneath the roadway, in which are situated the automatic switches by means of which the successive contact studs on a section of the line are successively connected with the source of electric power.

Box, Distributing, a box into which one or more circuits enter, to be split up into a greater number of smaller circuits for distribution from the box. Some form of small bus-bar is generally used as the centre to which the incoming and outgoing conductors are attached, and fuses, and sometimes switches in addition, are often placed in the box in as many leads as desired. Distribution boxes are made of various materials, and are of various designs, depending upon whether they are to be placed under or above ground, &c. When used in the wiring of buildings the boxes are often of wood, with a glass door secured by a lock and key, and the fuses and other fittings are mounted on a slate or marble panel within. (Ref. 'Practical Electric Light Fitting', Allsop.)

Box, Dividing, a water-tight case enclosing a lead-covered cable located at a



Dividing Box

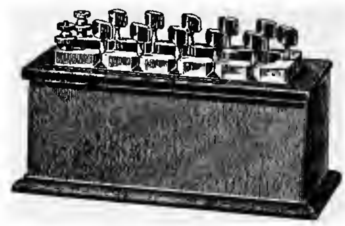
point where the cable is tapped off from a straight run. The figure represents a dividing box for an 11,000-volt, three-phase, lead-covered cable. It is important, at a dividing box, to bond the lead sheathing of the cable to the box. See Box, Trifurcating; Box, Bifurcating.

Box, Feeder. See Feeder Box.

Box, Fuse. See Fuse Box.

Box, Joint, a receptacle, usually of cast-iron, into which the ends of cables and wires are brought for the purpose of being connected together. The cables and wires are brought through stuffing boxes, and the lid joint is packed with indiarubber, so that when closed up, the whole is water-tight. The connections may be screwed or soldered, and in some cases, after the connections have been made, the box is fitted up solid, with a bitumen compound poured in hot. The object of the joint box is to sufficiently insulate and protect the connections. See also High-tension Cable Joint.

Box, Resistance.—This term is applied to a box containing a number of resistance coils whose values have been carefully adjusted and arranged in such a way that any resistance from zero to the total amount may readily be obtained by varying the



Resistance Box

position of plugs or of dial switches. See also Bridges.

Box, Section, a box, generally of cast iron, in which sections of cables are joined together (see Box, Cable). By disconnecting at section boxes, the various sections of a cable system may be separately tested. Instead of boxes, cast-iron pillars with disconnecting links or switches in easily accessible positions are often used for street work; the doors of the pillars are provided with locks, and often a telephone, or terminals to which a portable telephone can be affixed, are added to the internal equipment.

Box, Service. See Cable, Service.

Box, Trifurcating, a cast-iron dividing box (see Box, Dividing) at which the three cores of a three-phase cable are branched off separately.

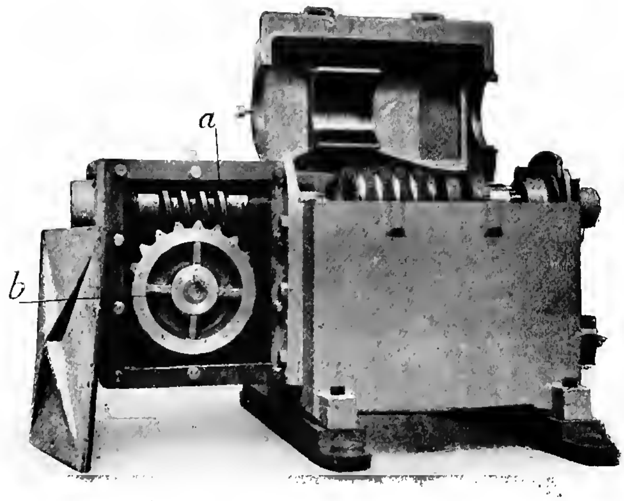
Box Sounding Relay. See Relay.

Box Type Brush Holder. See Brush Holder.

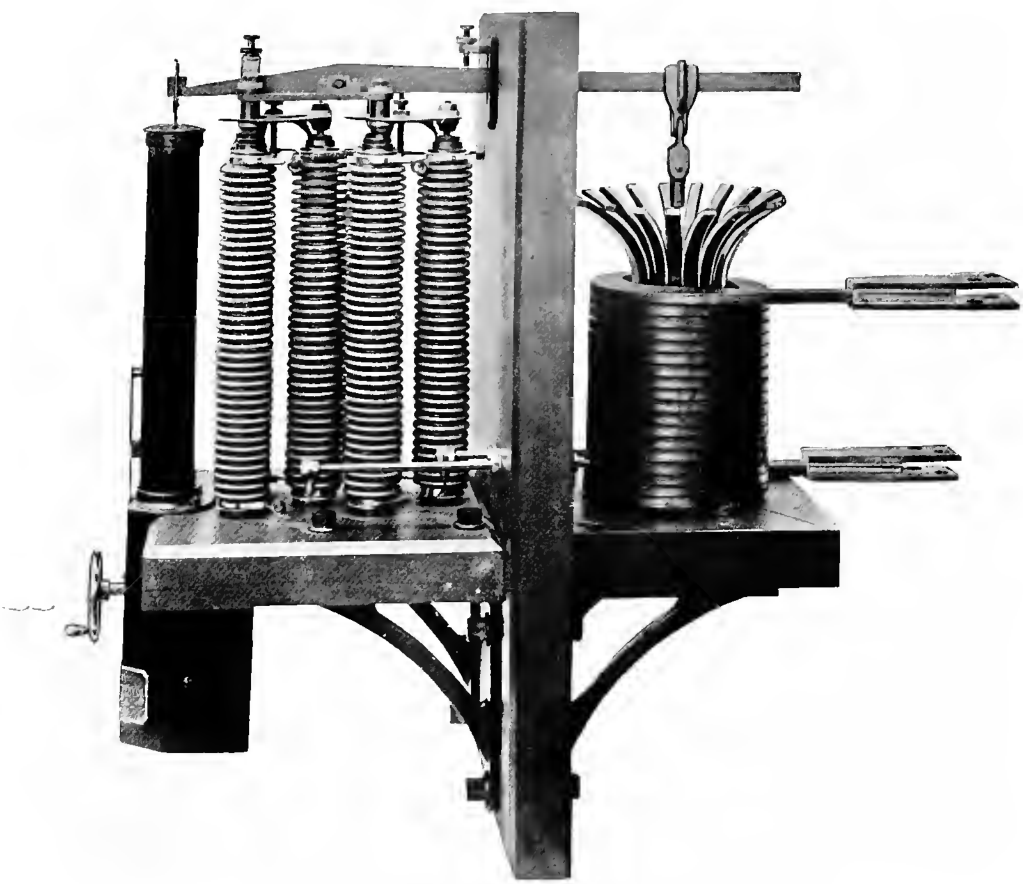
Box Type Frame. See Frame, Stator.

Brace, Cross-arm. See Cross-arm Brace.

Bracket Arms, arms projecting at right angles from the poles on electric traction routes, and arranged to carry the overhead wires. The bracket arms are generally made of tubing, some 6 to 8 cm in diameter, and are secured to the poles by *collars* of malleable cast iron and by more or less artistic scrollwork and tie rods. With brackets up to some 2 m in length, tie rods are not, as a rule, employed, and the bracket is supported by the collar and the scrollwork alone. With lengths from 2 m up to 4 or 5 m a single tie rod is generally added, and two tie rods are employed for greater lengths. The tie rods are generally made



WORM GEAR FOR ELECTRIC MOTOR (see p. 237)



CARBON REGULATOR OF THE ENTZ BOOSTER

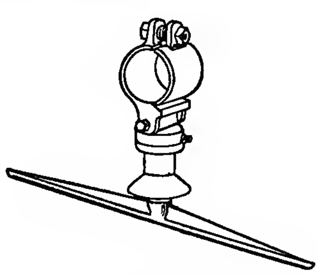
[To face p. 58.

of rod of some 20 cm diameter. The bracket-arm hangers that carry the trolley-wire ears are clamped to the arm, or, where smoother running of the trolley is desired, two small malleable-iron castings, about 1 m apart, are clamped to the bracket, a short span-wire fixed between them below the bracket, and the straight-line hangers attached to the span wire. Sometimes a bracket arm carries only a single trolley wire, but as a general rule it carries two — one for the traffic in one direction, the other for the traffic in the other direction. Where the poles are placed in the centre of the road bracket arms are fitted on each side of the poles, and in some cases the arms are arched in shape instead of being straight, and a short span-wire carrying a straight-line hanger is stretched across each.

When a span-wire connection is adopted, that is to say, when the trolley wires are suspended from span-wires stretching across the roadway, the poles are sometimes provided with short brackets about 50 cm or so in length, to the end of which the span-wires are attached. These short brackets are generally ornamented with a small scroll-work, and are supposed to improve the appearance of the line; it is, however, doubtful if they achieve the desired end.

Wooden bracket arms are sometimes employed with wooden poles on small trolley lines worked for industrial purposes in connection with mines, &c. Special bracket arms are also used on electric-light poles to carry arc lamps, &c. See also SUSPENSION, TROLLEY-WIRE. (Ref. 'Modern Electric Practice', vol. iv; 'Electric Traction', Wilson and Lydall.) [F. W.]

Bracket-arm Hanger, a fitting for supporting an overhead trolley wire from



Bracket-arm Hanger

a bracket-arm, generally made of bronze or of malleable iron, and consisting of a clamp for gripping the bracket-arm, a metal bell-shaped protecting piece, and inside, but insulated from it by a special insulating material, a bolt to which the ear carrying the wire can be screwed. See figure. (Ref. 'Modern Electric Practice', vol. iv; Dawson's 'Engineering and Electric Traction Pocket Book'.)

Bradley's Method of Starting Induction Motors. See STARTING OF MOTORS.

Braided Flex, a flexible conductor made up by braiding the conductors. A sufficient number of braids are laid over each other to make up the required section.

Braided Wire. See WIRE, BRAIDED.

Braiding.—

['*Braiding*, a plaited covering of fibrous material or wire (verb, to braid).'—I.E.C.]

Brake Levers, the levers by means of which a comparatively small force is enabled to produce a very great pressure between the brake blocks and the rims of the wheels or the rails.

Brake Magnets in Meters. See METER, RETARDING TORQUE OF THE MAGNETIC BRAKE.

Brake Notches, the positions of a car controller in which the electric brake is brought into action.

Brake Rigging, the system of links, chains, and levers by means of which the brake shoes are applied to the wheels of a car to stop its motion.

Brake Shoe, a cast-iron or wooden block which is pressed against the rim of a car wheel, or against the track rails, in order to retard the motion of the car or to hold it stationary.

Brakes.—In electric traction, a considerable variety of brakes are employed. Generally the final retardation is ultimately accomplished by the friction of brake shoes on the periphery of wheels, but electromagnetic and mechanical wheel and track brakes, and also regenerative braking, are also employed, particularly at the commencement of retardation and continuing down to moderately low speeds.

AIR BRAKE. — In electric as in steam traction, the brakes are often actuated by compressed air, derived either from a storage tank or from an air compressor carried on the car or locomotive, and driven either by an electric motor or from one of the axles. The brakes are applied by the admission of compressed air to a cylinder, actuating a piston connected with the brake gear. Air brakes of the vacuum type, in which the brakes are applied by atmospheric pressure, are also in use on electric railways.

ELECTRIC BRAKE, any type of brake depending for its action upon an electric current. There are several different types of electric brake, mostly employing the current generated by the motors acting as generators; they are used on tramcars and electromobiles, and occasionally on railway trains. In the *Rheostatic Brake* the motors are reversed or cross-connected, and are connected with a rheostat to absorb the energy generated. In the *Emergency Brake* the motors are reversed and short-circuited upon themselves, the large current generated producing a powerful braking torque. Special notches are usually provided on the controller to bring these brakes into action, but when these are absent the emergency brake can be applied by reversing the motors and placing the controller in the full parallel position. The motors may also be reversed while current is still supplied from the trolley wire, and the controller moved into the starting position, thus applying power from the line to retard the motion of the car. To prevent a car from running back if stopped whilst ascending an incline, a *Run-back Preventer* is sometimes applied, consisting of controller connections which short-circuit the motors in the 'off' position.

ELECTROMAGNETIC BRAKE.—This term is applied to braking systems in which the retardation is produced by friction between surfaces held together by magnetic attraction. An early form, the *Electromagnetic Disk Brake*, consisted of two iron disks, one of which contained a magnetising coil actuated by current derived from the motors acting as generators. When energised, the two disks are drawn together with great force, and, one being fixed to the truck frame while the other is made fast to the axle, a powerful retarding force is produced. (Ref. Journ. I.E.E., vol. xxvi, p. 379.) Modern forms employ friction between cast-iron shoes and the track rails, the former being pressed into close contact with the latter by magnetic attraction, due to solenoids energised by the motors acting as generators. In the *Newell Electromagnetic Track Brake*, in addition to the friction thus produced, the brake shoes are applied to the rims of the wheels by the drag of the track brake, and the torque applied to the motors to generate the magnetising current also retards the motion of the car. In the *British Thomson-Houston Track Brake* the action is similar, but the track brakes are not connected to the wheel brakes.

REGENERATIVE BRAKING is a feature of some systems, and consists in sending back into the line some of the energy of momentum of the car or other moving body to be retarded, instead of dissipating this energy in heat at the brake shoes. See REGENERATIVE CONTROL SYSTEMS; MINING EQUIPMENT, ELECTRICAL; CRANE, ELECTRIC.

TRACK BRAKE, a brake which is applied to the track rails of an electric tramway, in order to produce frictional resistance to the motion of the car.

SLIPPER BRAKES, wooden blocks or shoes, which are carried beneath a tramcar and are pressed down on the track rails by means of levers in order to retard the motion of the car or to hold it at rest.

PNEUMATIC TRACK BRAKE, a system of braking applied only to tramcars, in which slipper brakes are pressed down upon the track rails by means of cylinders supplied with compressed air, and which can be applied at the will of the driver. An air compressor is carried on the car to provide the compressed air. See also CRANE, ELECTRIC.

[A. H. A.]

Brakes for Testing. See DYNAMOMETER, ABSORPTION; WATER BRAKE; PRONY BRAKE; BAND BRAKE.

Braking, Regenerative. See BRAKES; also MINING EQUIPMENT, ELECTRICAL.

Braking Distance, the distance traversed by a car or train before coming to rest after the brakes have been applied. The speed at which the car is travelling at the moment of application of the brakes, the condition of the rails, and the gradient, are conditions affecting the shortest attainable braking distance for a given braking mechanism and vehicle.

Branch Circuit. See CIRCUIT, BRANCH.

Branch Cut-out, a cut-out in a circuit that branches off the main circuit. See CUT-OUT.

Branch Distribution Boards. See WIRING SYSTEMS.

Branly Coherer. See COHERER.

Branly Tube Coherer. See COHERER, FILINGS.

Braun's Cathode-ray Oscillograph. See OSCILLOGRAPH.

Brazing, Electric. See WELDING, ELECTRIC.

Breadth Coefficient, used in the calculation of the electromotive force of alternators in order to allow for coils which may span only a partial pole pitch, sometimes called *pitch factor* (which see). The breadth coefficient may be introduced into formulæ for calculating the emf of ac machines, and thus takes into account the angular breadth of the coils. If all the conductors making up any one winding are concentrated in one slot per pole, the emf generated in any one conductor will be in phase with that generated in all the others, and the total emf will be the algebraic sum of that generated in all the conductors separately. If, however, the winding is disposed in several slots, or is spread over a considerable area, the linking of the magnetic field with the different turns will not occur simultaneously, and there will therefore be a difference of phase in the emf generated in the different conductors, depending upon their relative positions. The total emf will then not be the algebraic but the vector sum of the separate emf in the different conductors.

If the distribution of the magnetic field is a sine function, and if the conductors of each phase are collected in one small slot per pole, the formula giving the emf is

$$E = 4{\cdot}44\,T N M$$

where T is the number of turns in series,
N is the periodicity,
M is the total number of magnetic turns per pole.

If g represent the breadth coefficient, this formula becomes

$$E = 4{\cdot}44 \times g \times T N M$$

if the winding be distributed in several slots or if the flux distribution be not a sine function. The value of g will depend on the number of slots per pole and also on the distribution of the magnetic field. The most important factor determining this distribution is the ratio of the pole arc to the pole pitch. In most textbooks will be found tabulated values of g for different ratios of pole arc to pole pitch and for different numbers of slots; some writers, instead of tabulating g, tabulate values of $4{\cdot}44 \times g$.

Break. See COIL, INDUCTION.

Breakdown Factor, the ratio of the maximum output which an induction motor can give, known as the breakdown load, to the normal full-load output. The abbreviation bdf is widely employed for breakdown factor. See CIRCLE DIAGRAM.

Breakdown Tests. See TESTING ARMATURES; TESTING JOINTS; TESTING TRANSFORMERS; TRANSFORMER, INSULATION TESTING.

Breakdown Torque. See CIRCLE DIAGRAM; BREAKDOWN FACTOR.

Breaking Strength, Electric. See ELECTRIC BREAKING STRENGTH.

Breech Cock. See LEAD BURNING APPARATUS FOR ACCUMULATORS.

Breech Pipe. See LEAD BURNING APPARATUS FOR ACCUMULATORS.

Bremer Arc Lamp. See LAMP, ARC.

Brennan Gyrostatic Monorail System. See MONORAIL ELECTRIC RAILWAY.

Bridge Hanger. See INSULATED HANGER.

Bridge Insulator. See INSULATOR.

Bridge Megger. See OHMMETER.

Bridges.—

I. BRIDGES FOR MEASURING THE RESISTANCES OF CONDUCTORS.—

Wheatstone's Bridge. — In this apparatus, four resistances, A, B, C, and X, are joined

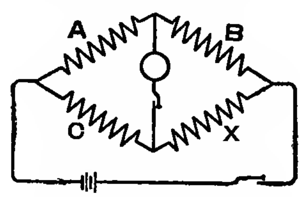


Fig. 1.—Wheatstone's Bridge

end to end so as to form a closed loop or quadrilateral, as shown in fig. 1. If either of the two pairs of opposite junctions be connected to a source of emf such as a battery, and any one or more of the four resistances be so adjusted that no difference of potential exists between the other pair of junctions, as is determined by joining these junctions through a galvanometer, then it is a consequence of Ohm's Law that the following relation subsists between the values of the resistances: A : B : : C : X.

In practice, the apparatus is so constructed that, by the use of plugs or contacts, the ratio A : B may be varied by multiples of ten, it being possible to give either A or B the values 1, 10, 100, and so on. The resistance C is made adjustable by steps of one ohm, or, more rarely, one-tenth of an ohm, by using plugs or sliding contacts. By these means the before-mentioned electrical condition may be produced in one apparatus, whether X, the conductor which it is desired to measure, be of large or of small resistance. Keys are provided for closing the battery and galvanometer circuits, and if the two keys are combined in one structure, it is arranged automatically to close the battery circuit first, so that any effects due to the inductance of any of the conductors, shall have subsided before the galvanometer circuit is closed. To reduce the effects of inductance to a minimum, it is usual to wind all the resistance coils of A, B, and C, non-inductively.

A *Post-office Bridge* is a compact form of Wheatstone's Bridge, employed for general work where neither very high nor very low resistances have to be measured. Variations of resistance are produced by the use of conical short-circuiting plugs, which, when in place between the contact blocks, effectively short-circuit the resistance connected between the blocks.

Slide Wire Bridge. — It will in general

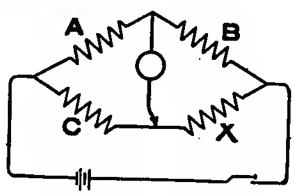


Fig. 2.—Slide Wire Bridge

happen that the value of X is such that the condition A : B : : C : X cannot be exactly established, as A, B, and C can be varied only by finite steps. In work of great refinement the slide wire bridge (see fig. 2) is sometimes used, as it enables an exact balance to be produced. In the slide wire bridge a fifth conductor is employed, connected between the two conductors, to whose junctions the galvanometer would be connected in the ordinary Wheatstone's Bridge. It is commonly a straight wire of non-oxidisable metal about 1 m long, and a spring contact is arranged to slide its whole length. To this contact is connected the galvanometer. The contact slides over a scale lying beside the wire, which has been calibrated so that its resistance over any length is known. On this apparatus it is always possible, by moving the spring contact, to find some point where an exact balance is produced, and the position of the contact read on the scale gives, with the values of the other resistances, A, B, and C, all the needed data for calculating X. A simplified form is shown in fig. 3.

The slide wire is also used in a simple way for determining the ratio of two resistances. In this case the slide wire may be considered as one of the adjacent pairs of conductors, the position of the spring-contact determining their ratio.

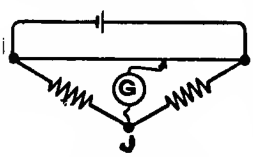


Fig. 3.—Simplified Slide Wire Bridge

Thomson Bridge.—This is a form of bridge for measuring very low resistances, such as short lengths of bars of large section, where the use of the ordinary Wheatstone Bridge would be quite inadmissible because of uncertainties due to contacts. Generally a standard slide wire is used, of a low resistance, preferably of the order of that of the specimen to be measured. The standard slide wire E and the test piece F are connected in series, and, at the time of measurements, are supplied with a considerable current, though not enough to cause appreciable heating, which would cause thermoelectric effects fatal to accuracy. Two sets of auxiliary resistances, A B and C D, are used, and are connected as shown in fig. 4. Between their junctions, the galvanometer is connected. The resistances are adjustable, but the ratio A : B is kept always equal to the ratio C : D. An approximate

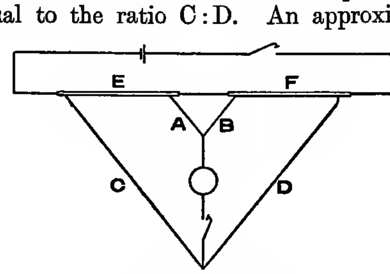


Fig. 4.—Thomson Bridge

balance is established by altering the ratio A : B, and the final adjustment is made by sliding the contact on the slide wire till the galvanometer is no longer affected by the main current. The ratio of the resistance of the test piece to the intercepted portion of the slide wire is, under these conditions, A : B.

Conductivity Bridge.—For the measurement of low resistances it is not possible to use the usual arrangement of resistances in series, varied by plugs or switches, as a standard, since their contact resistance would introduce serious errors. Hence for low-resistance measurements, the resistances are arranged in parallel, so that a comparatively high-resistance path may be added in parallel to reduce the resistance of any one 'arm'.

Meter Bridge.—Slide wire bridges are often arranged with an effective length of wire equal to 1 m. This wire is divided into mm. The arrangement is then spoken of as a meter bridge.

Carey Foster Bridge.—This instrument is a modification of the slide wire bridge, and is used for comparing very low resistances of like magnitude.

The Dial Form of Wheatstone Bridge has the resistances connected to stops over which a switch arm travels. The arms corresponding to A and B of fig. 1, each consist of one such switch dial, and the arm C consists of as many dials as there are significant figures in the required result. Thus a bridge to measure to four significant figures would have four dials to arm C, reading units, tens, hundreds, and thousands respectively.

Callender's Recording Wheatstone Bridge or Potentiometer, an instrument in which resistance or potential is automatically recorded on a strip of paper moving over a clockwork drum. The galvanometer employed carries a 'boom', which makes contact in either of two relay circuits according to the direction of its deflection. These relays release either of two clockwork motors, which adjust the bridge or potentiometer to balance and at the same time move a pen which indicates on the drum the position at which a 'balance' is found. This instrument may be used in conjunction with a platinum thermometer for recording temperatures or with an actinometer for recording light variations, &c.

British Association Bridge, a Wheatstone Bridge adjusted, in accordance with former requirements, to the British Association Standard of resistance (see OHM). All modern bridges are, however, adjusted to give readings in legal ohms (which see).

II. BRIDGES FOR MAGNETIC MEASUREMENTS.—

The Holden Permeability Bridge affords a means of comparing the permeability of an iron bar with one of the same length and similar magnetic properties. The two bars are linked at their ends by solid 'yokes' of soft iron, and over each is wound a magnetising coil. If the currents in the two coils are now adjusted so that there is no magnetic leakage between the ends as shown by a magnetometer placed in the centre, it follows that both are carrying the same total flux. Knowing the ats on one iron bar and its permeability, the permeability of the other may be calculated from their relative cross sections, lengths, and ats.

The Ewing Permeability Bridge.—Two bars of equal length and similar magnetic properties are linked at their ends by soft-iron yokes. From each yoke is brought out a horn of soft iron, the two horns almost meeting on either side of a magnetometer. The mmf on each bar are then regulated by varying the current and number of turns in coils surrounding them until the magnetometer indicates that both yokes are at the same magnetic potential. It follows that the ats around each bar are those required for the respective bars, and the permeability of one may be deduced if that of the other is known. See BAR AND YOKE METHODS.

Eickemeyer Bridge.—This bridge is probably the earliest application of the 'balance' principles to the measurement of magnetic properties. It differs from the Holden permeability bridge in that the magnetising coil is wound around the yokes instead of uniformly along the length of the two bars, and in that equilibrium was established by adding more or less to the section of the standard of comparison by the use of supplementary bars. (Ref. 'Elec. Eng.', New York, March 25, 1891.)

Bridging Cable. See CABLE, BRIDGING.

Brighton Maximum-demand System. See TARIFF SYSTEMS.

British Association Bridge. See BRIDGES.

British Association Ohm. See OHM.

British Association Unit of Resistance. See OHM.

British Candle. See CANDLE POWER.

British Thermal Unit, a heat unit not recognised outside of Great Britain and her Colonies, and the United States.

['*British Thermal Unit,* the quantity of heat required to raise a pound of water one degree from 60° F. to 61° F. Abbreviated 'B Th U'.'—I.E.C.]

British Ton. See TON.

Bronzkol Brushes. See BRUSHES.

Brooklyn Strain Insulator. See INSULATOR; TURNBUCKLE.

Brown & Sharpe Wire Gauge. See WIRE GAUGE.

Brown's Detector, a hf current indicator for use in wireless telegraphy. It consists of a small piece of peroxide of lead (as in the positive plate of an accumulator) between contacts of lead and platinum. This combination gives a pressure of two volts, which, in use, is counterbalanced by a cell in circuit with a telephone. The received hf current partially annuls this pressure, leaving the cell unbalanced, and thus producing a current which affects the telephone, rendering audible the signals transmitted by the received current.

Brown's High-frequency-current Generator, an oscillating circuit in parallel with a constant-current circuit in which the current flows from a small copper block to an aluminium disk, against the edge of which the copper is lightly pressed, while the disk slowly rotates about its centre.

Brush—Brushes.—A brush is a block of carbon or other suitable material, which is caused to bear upon a commutator or upon a slip ring, and so collects the current from the revolving part of a machine.

['*Brush*, a conductor for collecting or delivering current from commutators or slip rings. Originally made of copper wires, afterwards of copper strips or gauze, or of carbon blocks.'—I.E.C.]

POSITIVE BRUSH OF A DYNAMO, the brush, or sets of brushes, from which current emerges from a machine. The convention regarding the direction of flow of current is illustrated by fig. 1, the current flowing in the direction of the arrow when the north pole of the compass turns towards the west, the conductor being placed directly over the needle.

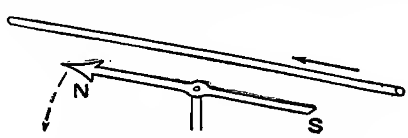


Fig. 1.—Direction of Flow of a Current

POSITIVE BRUSH OF A MOTOR, the brush, or the set or sets of brushes, at which the current enters a motor, it being remembered that the current enters a motor against the emf of the motor.

NEGATIVE BRUSH OF DYNAMO OR MOTOR, the brush of polarity opposite to that of the positive brush, as above defined.

ROTATING BRUSHES.—When the armature of a cc machine is the stationary member, it is necessary for the commutator brush gear to revolve in synchronism with the magnet poles, the current afterwards being carried to the line by way of a pair of slip rings. Such an arrangement is used on the Hutin & Leblanc 'permutator' for rectifying ac into a unidirectional one (Ref. 'Elec.', Dec. 8, 1905, and Feb. 9, 1906), and in other types of apparatus.

LAMINATED BRUSH, a type of brush probably first introduced by Mordey, and consisting of a number of separate sheets all insulated from one another, and so introducing resistance in a transverse direction. This transverse resistance reduces the short-circuit currents which flow between adjacent segments across the brush face. Radially the brush is free to carry the current in the ordinary way. Fig. 2, copied from Mordey's original paper, illustrates his plan.

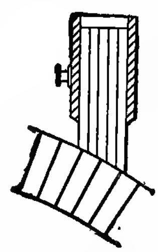


Fig. 2.—Laminated Brush

COPPER BRUSHES.—In the early days of the electrical industry, dynamo brushes were usually made of copper, either in the form of woven gauze, of leaf copper rolled in a number of layers, or of fine wires packed together and held in place by a band. A higher current density at the contact is possible with copper brushes as compared with carbon brushes, but the former have not been found as satisfactory as the latter from a commutation point of view, and their use for this purpose has been almost entirely discontinued. They are, however, sometimes used on the slip rings of ac machinery. It is sometimes a good plan to run a copper brush in conjunction with a carbon brush, as, although the former will carry the bulk of the current, it has rather a high friction loss, and the carbon will tend to lubricate the surface of the commutator or slip ring.

WIRE-GAUZE BRUSHES (sometimes termed *gauze brushes*), brushes consisting of copper gauze folded upon itself to make a brush of any desired size. This form of brush is nowadays used chiefly for slip rings, and the gauze is sometimes filled with solder to prevent the various wires fraying. The wire gauze is usually of fine mesh, cut diagonally, rolled up and compressed to a rectangular section.

Carbon Brushes.—The use of carbon as a material suitable for collecting current from the revolving member of a cc machine was suggested by Prof. Forbes in 1885. The superiority of carbon over copper brushes lies largely in the fact that the resistance of their contact with the commutator is far higher, and they thus limit the current which flows in the armature coils as these become short-circuited in succession by the brushes. In this way the sparkless collection of the armature current is facilitated. See also Pigtails for Carbon Brushes.

Compound Brush of Metal and Carbon.—Various types of compound brush have been used from time to time. The simplest comprises layers of copper and carbon side by side, the carbon being on the trailing side, and by this means, a higher resistance is offered to the current, as the commutator segments pass to that end of the brush where the circuit is interrupted.

A more recent type of compound brush is one in which finely divided copper is introduced into the body of the brush during its manufacture, the object in this case being more particularly to improve the electrical conductivity of the brush material and make it suitable for working with higher current densities.

Bronzkol Brushes, a composite brush, recently introduced, consisting of copper, tin, and carbon, prepared (according to the maker's leaflet) in the following manner:—

'The brushes consist of pure powdered graphite, each particle being covered, by a special process, with a coating of copper and then with one of tin. This copper- and tin-covered graphite powder is then compressed by hydraulic pressure to the required shape, without any kind of binding material such as is used for pure carbon brushes. Afterwards the brushes are heated sufficiently to make the copper and tin combine so that every particle of graphite powder gets a coating of bronze.'

The material has the appearance of brass, but is plastic like lead. After cleaning, or when freshly scraped, it can be readily soldered. It also possesses lubricating qualities on account of the graphite (about 20 per cent by volume) which it contains. Both the conductivity of the material and the contact resistance are much lower than in the case of carbon, and it is claimed that bronzkol brushes may therefore be used at higher current densities.

Morganite Brush, a brush made by the Morganite Crucible Company, of Battersea. Certain grades of the Morganite brushes have a greater transverse resistance than radial resistance, this being with a view to improving commutation by limiting the short-circuit currents which pass when two or more commutator segments are short-circuited by the brush at one time. See Brushes, Grading of.

'Le Carbone' Brushes, brushes manufactured by the 'Le Carbone' Company, of France. The firm make various grades of carbon and graphite brushes, suitable for a variety of purposes.

Endruweit Brush, a type of dynamo brush in which the carbon is interleaved with very thin copper foil. Such a brush appears to be constructed by winding together copper foil and paper, pressing to the required shape, and then carbonising the paper by an incandescent process. For those grades of Endruweit brush where there is but a very small proportion of copper, the copper appears to have been electrolytically deposited on thin slabs of carbon, and these slabs are then combined into a stratified brush by some incandescent process. This brush is also known as the *Galvano Metal Paper Brush.*

Pilot Brush.—When the brushes in one set consist of, say, four or five, it is sometimes the practice to set one brush farther forward than the rest, so that the current is finally broken at a reduced contact area, thus conducing to better commutation. This brush is known as a 'pilot' brush, and, in order to obtain the best results possible with this scheme, the pilot brush is sometimes made of a higher-resistance material than the other brushes.

The term is also used in another sense, namely, when a small brush is used for exploring purposes. In cc machines it is very often useful to know how the flux is distributed across the pole face at various loads. For this purpose a small brush, insulated from the main brush studs, is allowed to trail upon the commutator, and the pressure is read between this and the main brushes when it is placed at different angular positions. In determining by resistance measurements, the rise of temperature of an alternator rotor, pilot brushes insulated from the main brushes are allowed to bear on the rings, and the pressure across these, gives the ohmic drop on the rotor windings, independently of the variable brush contact resistance. [H. W. T.]

Brush Arc-light-Dynamo Regulator. See 'Carbon Regulator' under REGULATOR, POTENTIAL.

Brush Box. See BRUSH HOLDER.

Brush Contact Resistance. See BRUSH RESISTANCE.

Brush Discharge, a faintly luminous electric discharge, usually accompanied by a slight hissing sound, which takes place from bare conductors at high potentials (*i.e.* some thousands of volts). It is apparently intermittent, even with constant pressures, and is more obvious on the positive than the negative electrode. Very fine effects of this type are obtainable with hf currents generated by means of an oscillating circuit and a 'Tesla' transformer (which see). [J. E.-M.]

['*Brush Discharge*, a discharge having a feathery form, and consisting of an intermittent partial discharge which takes place from a conductor when the potential difference exceeds a certain limit, but is not high enough to cause the formation of a true spark or arc. It is always accompanied by a hissing or crackling sound.'—I.E.C.]

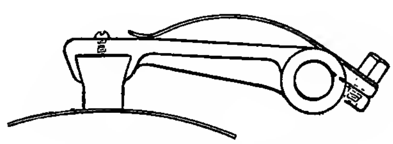


Fig. 1.—Arm or Lever Type

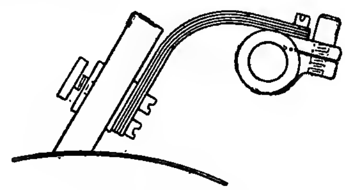


Fig. 2.—Spring-arm Type

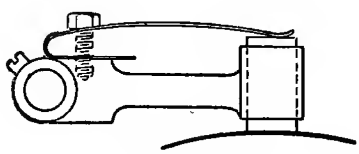


Fig. 3.—Box Type

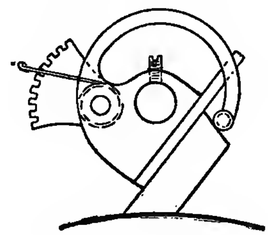


Fig. 4.—Reaction Type

Brush Holders

Brush Displacement. See DISPLACEMENT OF BRUSHES.

Brush Frictional Loss. See LOSS, BRUSH FRICTIONAL.

Brush Heel, that side of a brush at which the commutator bar first makes contact. See also BRUSH TOE.

Brush Holder, a device for providing a mechanical support for a brush for collecting the current from the revolving collector or commutator of a dynamo electric machine. Most brush holders fall within one or other of four types:

1. Arm or Lever type.
2. Spring-arm type.
3. Box type.
4. Reaction type.

1. In the *Arm or Lever type* (see fig. 1) the brush is firmly attached to the extremity of a rigid arm capable of movement about the brush spindle, except in so far as it is restrained by a spring.

2. The *Spring-arm type* is illustrated in fig. 2. The brush is firmly attached to the extremity of a spring arm, the other end of which is secured to the brush spindle, and when once adjusted is not capable of movement about the brush spindle.

3. The *Box type* brush holder is illustrated in fig. 3. The brush is free to move up and down in the *brush box*, so far as it is not restrained by a spring rigidly secured to the arm which carries the brush box at its extremity.

4. In the *Reaction type* of brush holder, illustrated in fig. 4, the movement of the brush is constrained in one direction by the surface of a part rigidly secured to the brush spindle, and is further constrained by a spring-controlled arm, the pressure of which is capable of ready adjustment.

There are also a number of special brush holders. The MORGANITE CRUCIBLE COMPANY'S PNEUMATIC BRUSH HOLDER, illustrated in fig. 5, has been designed for use on extra-high-speed commutators, and com-

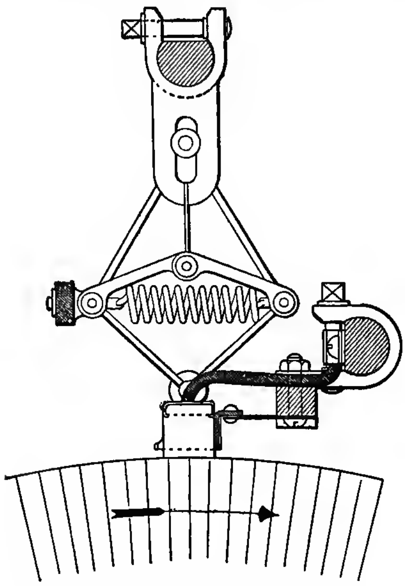


Fig. 5.—Morganite Pneumatic Brush Holder

prises arrangements whereby the pressure is provided by means of compressed air supplied from an external source.

SCISSORS TYPE OF BRUSH HOLDER, a type of brush holder used for slip rings, consisting of two arms pivoted together like a pair of scissors. The lower ends of the arms carry the brushes, suitably mounted, and the upper ends are drawn together by a spring, which thus exerts pressure on the brushes. See also CLOCK-SPRING BRUSH HOLDER; PIGTAILS FOR CARBON BRUSHES.

The subject of brush holders is given full treatment in chapter xix of Hobart and Ellis's 'High-speed Dynamo Electric Machinery'.

['*Brush Holder*, the apparatus which holds the brushes.'—I.E.C.]

Brush Company's Type of Interlocking Commutator Segment. See COMMUTATOR SEGMENT.

Brush-lifting Device.—In the wound-rotor type of induction motors, slip rings are often provided, so that resistance may be inserted in the rotor circuit for starting up. In such motors *short-circuiting devices* are often provided to relieve the brushes of the current when full speed is reached. There is still the friction loss at the brush contact, and an attachment is often provided so that the brushes are lifted from the rings at this stage. The brush-lifting device should be interlocked with the short-circuiting device, so that the former cannot be operated until the latter is in place.

Brush Position. See BRUSHES, ADJUSTMENT OF.

Brush Pressure, the mechanical pressure brought to bear upon brushes, usually by the intervention of springs, which keeps them in good electrical contact with the commutator or slip ring.

The losses at brush contacts are due to friction and to the electrical resistance of the contacts. An increased pressure upon the brushes, gives a higher friction loss but usually a slightly reduced contact I^2R loss, and, with a given set of conditions, it is advisable to balance these losses against one another and adopt such a brush pressure as to give a minimum total loss, care being taken to see that the pressure is not so reduced as to allow the brushes to chatter, through irregularities in the commutator.

Most makers state the pressure and current density which they regard as most suitable.

Brush Resistance.—Strictly speaking, the term *brush resistance* should be considered to relate to the resistance of the brush itself. The term is, however, frequently used to denote the *brush contact resistance.* As a matter of fact, the resistance of the material of the brush is usually of less importance than the contact resistance between the material of the brush and the material of the commutator segments.

BRUSH CONTACT RESISTANCE.—The more or less imperfect contact existing between a brush and a commutator or slip ring, introduces an appreciable resistance which varies with a large number of conditions, such as the material of which the brush and slip rings are made, the condition of the surfaces, the speed at which the rings rotate, the mechanical pressure between the two surfaces, the temperature of the two surfaces, the current density at the contact, and the direction in which the current flows, *i.e.* whether from brush to ring or from ring to brush. The chief factors, apart from the materials used, are the pressure and the current density. An increase of pressure generally somewhat diminishes the contact resistance, and as a general rule the same effect is obtained with an increased current density, the contact therefore not obeying Ohm's law. As regards actual values, makers supply figures for their own various brands of brushes. The fairly high contact resistance between the carbon brush and the commutator is a factor of some importance in the modern theory of commutation, and for a complete understanding of this latter, a knowledge of the physical properties of the various kinds of brushes in use, is essential.

TRANSVERSE RESISTANCE OF BRUSHES, the resistance of the brush material across the leading and trailing faces. Brushes have now been in use for some years which have a greater resistance in the transverse direction than in a radial direction. The object of this is to limit the short-circuit current which passes under the brushes when two or more commutator segments are short-circuited at the same time. Originally brushes for this purpose were made up of a number of parallel blocks, with some insulation, such as paper, between the blocks, but recently solid brushes have been introduced, the desired object being obtained by a special process of manufacture. See BRUSHES.

Brush Rigging, the metal framework which constitutes the mounting for the brush holders of dynamo electric machines. In small machines, this consists of an armed spider, mounted on one of the bearings, the brush spindles, and the brush rocking gear. In larger machines it comprises the brush rocker ring, with its supporting arms, the brush spindles and the rocking arrangements. See BRUSH ROCKER; BRUSH YOKE.

Brush Rocker, the cast-iron structure which is supported from the magnet frame and is capable of circumferential movement, so that the brushes, for which it acts as a mounting, may be adjusted to the best position for commutation at different loads. See BRUSH RIGGING; BRUSH YOKE.

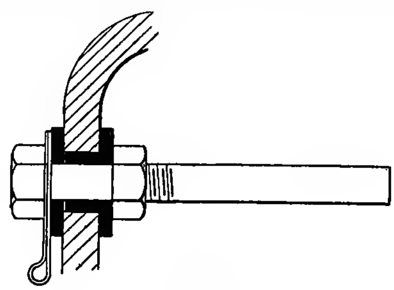
['*Brush Rocker*, the apparatus which enables the position of all the brushes carried by it to be altered simultaneously in either direction.'—I.E.C.]

Brush-shifting Device, an arrangement for setting the brushes to different angles of lead at different loads. *Automatic brush-shifting devices* have been used on some turbo-dynamos. Brush-shifting devices are, however, generally manually operated.

Brush Springs, the springs by which, in some types of brush holders, a suitable pressure is maintained between the brushes and the commutator surface.

Brush Stud, the stud or brass spindle upon which all the brushes in a set are clamped, and which is bolted to the end shield or to some other convenient member of the machine.

As regards insulating the brushes from the frame, two methods are adopted. By the first method, the studs are bolted straight to the frame, the brushes being mounted upon an insulating tube which fits tightly around the stud. By the second method, the brushes are clamped straight on to the stud, the insulation being provided at the point where



Brush Stud

it is fixed to the frame. The second method is indicated in the figure.

Brush Toe, that side of the brush at which the commutator bar finally breaks contact. The term arose at the time when copper brushes, fitted to the commutator at an angle, were in universal use. See BRUSH HEEL.

Brush Yoke, in large machines, the framework, usually of cast iron, which is supported from the magnet frame, which is capable of a certain amount of circumferential movement, and which forms a rigid support for the various sets of brushes. See BRUSH RIGGING; BRUSH ROCKER.

Brushes, Adjustment of. — In the earlier cc dynamos and motors copper brushes were employed, and it was only possible to obtain good commutation (which see) by changing the position of the brushes as the load changed. With the increasing variety of applications of electric motors to various purposes, however, it often became necessary that the motors should run with fixed-brush position, since the load often varied so rapidly that it was impracticable to alter the position of the brushes. This state of affairs led to the development of carbon brushes, which, if used with suitably designed machines, led to good commutation with fixed brush-position. With motors only requiring to be run in one direction, the fixed brush-position could be at a certain angular position from the geometrical neutral points, *i.e.* from the positions midway between two adjacent poles. For reversible motors, however, the brushes must remain at the geometrical neutral point for both directions of rotation as well as for all loads. This requirement, and, further, the exacting requirements accompanying the introduction of variable-speed shunt motors, and, finally, the difficulties attending the design of high-speed cc dynamos and motors, are apparently leading rapidly to the extensive use of interpoles (which see) and compensating windings (which see). When these are used, the brushes are set, once for all, at the geometrical neutral point, and in such machines there is no subsequent adjustment of the brushes. See COMMUTATION.

Brushes, Angle of Lead of. See ANGLE OF LEAD.

Brushes, Chattering of, brushes making imperfect and varying contact with the commutator, due to irregularities in the commutator surface, to insufficient pressure on the brush, or to the brush being narrow and loose in its box. Even under the most favourable conditions, it is very difficult to eliminate chattering when carbon brushes are employed on commutators running at a very high peripheral speed. In many cases a little vaseline must be applied every hour or so in order that the noise shall not become intolerable.

Brushes, Grading of.—In order to improve commutation, brushes have been used consisting of a number of layers of varying purities, so that the trailing end of the brush, *i.e.* that portion from which the current is finally broken, offers a higher resistance to the current, and the greater proportion is collected on the front side of the brush.

The term may also be used in connection with a more recently introduced type of brush, in which the transverse resistance of the brush is made greater than the radial resistance, and so limits the short-circuit currents when two or more commutator segments come under the brush at the same time. See COMMUTATION; BRUSHES; BRUSH RESISTANCE.

Brushes, Sparking at. See SPARKING OF DYNAMO-ELECTRIC MACHINERY.

Brushes, Staggering of.—In order that brushes, when there are two or more in a set, shall not wear grooves in the surface of the commutator, the brushes in one set are placed slightly to one side, so that they bear upon that part of the commutator which lies between the various brushes in the other sets.

In some turbo-dynamos, the whole of the positive brushes have been mounted at one end of the commutator, and the whole of the negative brushes at the other. It is claimed that this arrangement minimises the liability to flashing over.

B Th U, the preferable abbreviation for British Thermal Unit (which see).

BTU, the preferable abbreviation for Board of Trade Unit (which see), and not to be confused with B Th U, the heat unit of the British system.

['*BTU* or *B.O.T.U.*, see BOARD OF TRADE UNIT. (Terms not recommended.)'—I.E.C.]

Bucket Conveyor. See COAL CONVEYORS.

Buckingham-Page Type-printing Telegraphy. See 'Type-printing Systems of Telegraphy' under TELEGRAPH SYSTEMS.

Buckling of Accumulator Plates. See ACCUMULATOR PLATES.

Buckling of Commutator Segments. See COMMUTATOR SEGMENT.

Buffer Battery. See BATTERY, BUFFER.

Buffer Machine, a dynamo-electric machine with considerable flywheel storage capacity, and otherwise so proportioned and arranged that when the load on the main generators is, for a brief period, high, the machine decreases in speed and delivers electricity into the line, thus drawing from the supply stored up in the flywheel. When the load has again decreased, the machine becomes a motor and is again driven up to speed, thus again constituting a source of stored-up energy. See 'Ilgner System' under MINING EQUIPMENT, ELECTRICAL.

Building Rings of Commutator. See RING, COMMUTATOR.

Bulb. See LAMP, INCANDESCENT ELECTRIC.

Bunching Coefficient. See GAP RELUCTANCE.

Bunching of Conductors in Protective Tubing.—The introduction of the practice of encasing interior wiring in metal tubing, while it is generally regarded as a distinct advance over the practice of running conductors in wooden mouldings, has nevertheless led to the running of many conductors in a single tube. With certain restrictions, this practice is sanctioned by the insurance companies and others responsible for maintaining a high standard in electrical wiring. When several conductors are thus carried they are said to be 'bunched' in the tube.

The 1907 Wiring Rules of the I.E.E. apply to the supply of electricity at low pressures not exceeding a maximum of 250 volts. The above term is, in these rules, defined as follows:—

'Conductors are said to be *bunched* when more than one is contained within a single duct or groove.'

The Wiring Rules above referred to, should be consulted in ascertaining the limitations imposed regarding the bunching of conductors.

Bunching of Magnetic Field. See GAP RELUCTANCE.

Bunching of Series Windings.—In the early days of electric traction the field windings of the motors, when operated in

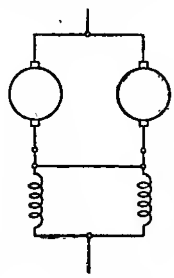


Fig. 1.—Bunched Connection

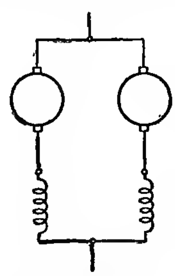


Fig. 2.—Independent Connection

Bunching of Series Windings

parallel, were 'bunched' as shown in fig. 1; that is to say, a conducting path of negligible resistance was provided from the point between the field and armature of one motor to the corresponding point of the other motor. This practice was found to be unsatisfactory, since the motors would not equally divide the load, and the practice has been long since discarded in favour of the method illustrated in fig. 2, which may be termed the 'independent' method of paralleling the motors.

Bunsen Battery. See BATTERY, PRIMARY.

Bunsen Flame Detector. See WIRELESS TELEGRAPHY, DE FOREST SYSTEM.

Bunsen Photometer Head. See PHOTOMETER HEAD, CONTRAST.

Buried Work, a term applied to interior wiring where the casings or tubes in which the wires are located, are concealed in the plaster of the walls and between the ceiling of one story and the flooring of the next upper story. When the tubes or wooden casing or the flexible wires are run along the surfaces, the work is described as *surface work* or *exposed work.* It is thus not necessarily implied that the *conductors* are exposed to view; while this would be the case in a flexible wiring system (see WIRING SYSTEMS), it would not be the case in *conduit wiring* or in systems where the wires are run in metal conduits.

Burke Interlocking Commutator Segment. See COMMUTATOR SEGMENT.

Burning Point of an Oil. See OIL, FIRE TEST.

Burnt Out.—A piece of electrical apparatus is said to be 'burnt out' when its windings, or the materials with which they are insulated, have been destroyed or rendered useless by heat generated by the passage of an excessive current.

Bus-bars, the conductors on a switchboard to which and from which the various circuits run. On lt switchboards the bus-bars are generally of copper or aluminium strip, carried by, but insulated from, brackets supported by the iron framework of the board.

On ht boards the bus-bars are generally of copper strip, which is sometimes carried by insulators mounted on brackets, or otherwise supported from the metal framework of the board at such a height as to be out of reach, and sometimes by insulators built into the walls of brick or stonework cells, which cells completely enclose the bus-bars and minimise the risk of accidental contact or short circuit. Sometimes heavily insulated conductors are employed instead of bare copper strip, but suitably protected bare bus-bars are better practice. (Ref. 'Electricity Control', L. Andrews; 'Modern Electric Practice', vol. ii.)

['*Bus-bar,* abbreviation for omnibus-bar. Conductors (generally on a switchboard and of comparatively large size) to which several mains or feeders are connected.'—I.E.C.]

MAIN BUS-BARS, the bus-bars on a switchboard to or from which the main supply circuits are run, as opposed to any subsidiary bus-bars provided for synchronising or other purposes.

GENERATOR BUS-BARS, the bus-bars on a switchboard to which the generator leads are attached. These are generally also the main bus-bars.

TROLLEY BUS-BARS, the bus-bars on a generating-station switchboard or substation switchboard to which the feeders which supply the trolley wires are connected. In most plants these are also the main bus-bars, though the term may be of service where it is necessary to distinguish these bars from ht bus bars or lighting bus-bars.

AUXILIARY BUS-BARS, bus-bars used for synchronising, cable charging, or other auxiliary purposes. These bus-bars are independent of the main bus-bars. See CABLE-CHARGING GEAR.

SYNCHRONISING BUS-BARS, the bus-bars on a switchboard, which are or can be connected to a *synchroscope*, or to *synchronising lamps*, and to which any desired circuit can be connected by plugs or switches when it is desired to synchronise that circuit with another source of supply, generally the main bus-bars. (Ref. 'Electricity Control', L. Andrews, under SYNCHRONISER CONNECTIONS.)

Bus-bar Transformer. See TRANSFORMER, INSTRUMENT.

Bus Line Coupler. See COUPLER, BUS LINE.

Bus Sectionalising Switches. See SWITCHES, BUS SECTIONALISING.

Bush, Commutator, the steel or iron sleeve or spider constituting a mechanical support for the commutator segments.

Bush, Insulating, a suitably shaped piece of durable insulating material for protecting electrical conductors. In conduit systems of electric wiring the conductors are protected from the metal edges of the conduit, at points where they emerge, by insulating bushes, which may, according to circumstances, be either *internal insulating bushes* or *external insulating bushes.* An example of each is shown in the figure.

Insulating Bush

Bushed Pole. See POLE, BUSHED.

Bushing, Condenser Type, an insulating bushing for the terminals of h pr circuits, such as the primaries of transformers, which comprises concentric layers of insulating material and tinfoil. It is claimed that, for a given aggregate thickness of insulation, this subdivision distributes the stresses more uniformly throughout the thickness of the insulation, than would be the case were the layers of tinfoil not employed.

Busy-back.—

['An electrical signal transmitted from one telephone exchange to another to indicate that the line wanted is in use.'—I.E.C.]

Butterfly Connections. See CONNECTIONS, BUTTERFLY.

Buttner Valve. See RECTIFIERS.

Butt-welded Joints. See JOINTING ALUMINIUM CONDUCTORS.

Buzzer, an electric bell without the gong, or similar mechanism for producing intermittent currents and a slight noise. Used in testing wireless-telegraphy apparatus, since high pressures and oscillatory currents are produced at each interruption. Also applied to a call signal device on certain types of telephone.

BWG, abbreviation for Birmingham Wire Gauge. See WIRE GAUGE.

By-product from Destructors. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

C

C, the chemical symbol for Carbon (which see).

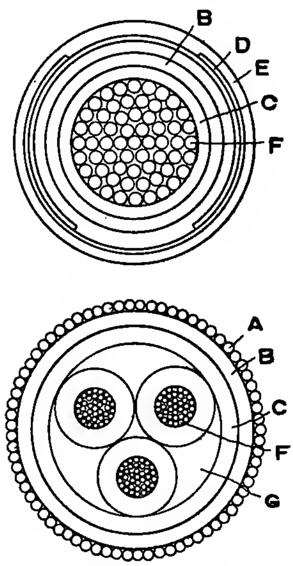
C emf, the preferable abbreviation for Counter Electromotive Force. See ELECTROMOTIVE FORCE, COUNTER.

Cab, Electric, an electromobile fitted with seats, usually for from two to four passengers, and plying for hire upon ordinary roads. See also ELECTROMOBILE.

Cable, a conductor consisting, when employed for transmitting an electric current, of a number of wires, usually either of copper or of aluminium, stranded together.

['*Cable*, for electrical purposes, a stranded conductor with or without protective covering.'—I.E.C.]

ARMOURING OF CABLES, a covering of steel wire (see lower figure) or steel tape (see upper figure) laid over the insulation or lead covering of a cable to protect it from mechanical injury. Strictly speaking, a covering of steel wire is called a *sheathing*, the term *armouring* being reserved for a covering of steel tape, but both are more often referred to as *armouring.* Steel wires for armouring vary in diameter from about 72 mils (1·8 mm) up to about 375 mils (9·5 mm). They are always galvanised to prevent rust, and are sometimes tarred as well. A serving of tarred jute or hemp is generally laid over the steel wire sheathing, and the whole finally compounded. Steel tape is, as a rule, laid on in two layers, the outer layer covering the joints in the inner layer. The steel tape is served over with jute or hemp, and compounded in a similar manner to steel-wire sheathing.



Armouring of Cable

A, Steel wire; B, lead; C, insulation; D, sheet steel; E, yarn or jute; F, copper; G, filling-in material.

STEEL-WIRE SHEATHING gives considerable tensile strength but no very great protection against sharp instruments such as picks, whereas *steel tape armouring* gives little or no tensile strength but affords considerable protection against picks.

UNARMOURED CABLE.—This is a cable the insulation or lead covering of which is not protected by steel wires or steel tape. See also CABLE, UNDERGROUND. (Ref. 'Distribution of Electrical Energy', J. F. C. Snell; M. O'Gorman in 'Electrician Primers', vol. ii.)

Cable, Aerial.—Cable suitable for being supported in the open on insulators, and either bare or, when required, protected by a covering against impurities in the atmosphere. It is generally made of high-conductivity hard-drawn copper wire, and the covering, if required, may consist of single, double, or triple braiding and compounding. See also CONDUCTORS, OVERHEAD.

Cable, Air-space, a cable in which the greater part of the dielectric between the conductors is air. Used in telephony because of its low inductive capacity, which minimises the condenser action of the dielectric, and consequently the attenuation of the transmitted waves. See CABLE, DRYCORE.

Cable, Association, a cable made in accordance with the standards of the *Cable Makers' Association,* an association of which a considerable proportion of the cable manufacturers of Great Britain are members. These cables are of high grade. The firms belonging to the Cable Makers' Association also manufacture lower-grade cables, as otherwise they would not be in a position to compete with outside manufacturers in Britain and on the Continent, in cases where the specification permits of lower grade. But these lower-grade cables are sold with the distinct understanding that they are not in accordance with the standards of the Cable Makers' Association.

Cable, Bridging, a short length of cable for cutting a cell out of circuit if there are indications that it is not in a healthy condition.

Cable, Capacity of, the electrical capacity of a cable or conductor. The capacity of a single-core, insulated, lead-covered cable in mfd per mile between the core and the lead is:

$$\frac{0{\cdot}0388\,k}{\log \frac{D}{d}},$$

where k is the specific inductive capacity of the insulating material, D the diameter of the cable outside the insulation, and d the diameter of the conductor. The charging current in amp is:

$$\frac{2\pi NKE}{10^6},$$

where E = line emf in volts, N = frequency, and K = capacity in mfd.

The following is deduced from a paper by Mr. M. B. Field:—

The capacity of a three-phase, three-core, lead-sheathed cable may be considered as a combination of capacities, as in fig. 1. We are justified in assuming that the capacity-effect of a multiple-core, lead-sheathed cable can be exactly represented by actual capacities between the individual conductors and between the conductors and the lead sheath. For, taking the case of a three-core cable, we know that if Q_1, Q_2, Q_3, V_1, V_2, V_3 represent the charges and potentials of the various conductors, the lead sheath being grounded, then we have the relations:

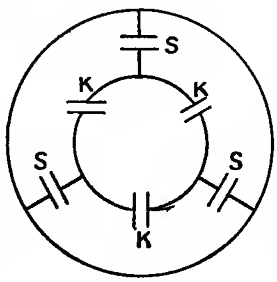


Fig. 1

$$Q = a_{1-1} V_1 + a_{1-2} V_2 + a_{1-3} V_3 \text{........(A)}$$

and similarly for Q_2 and Q_3, where the 'a' coefficients are constants of the same dimensions as capacity.

Now, if we consider capacities K_{1-2}, K_{1-3}, K_{2-3} connected between the conductors, and K_{1-s}, K_{2-s}, K_{3-s} connected between the conductors and sheath, we have:

$$Q_1 = K_{1-2}(V_1 - V_2) + K_{1-3}(V_1 - V_3) + K_{1-s} V_1 \text{......(B)}$$

and similarly with Q_2 and Q_3.

This can be written as:

$$Q_1 = (K_{1-2} + K_{1-3} + K_{1-s}) V_1 - K_{1-2}V_2 - K_{1-3}V_3.$$

$$\text{Hence } a_{1-1} = K_{1-2} + K_{1-3} + K_{1-s}$$
$$- a_{1-2} = K_{1-2}$$
$$- a_{1-3} = K_{1-3}, \text{ and so on.}$$

We therefore see that (B) is only another way of writing (A); if then we determine K_{1-2}, K_{1-3}, K_{1-s}, &c., by experiment, we can consider these as actual capacities connected, as represented in fig. 1 and equation (B).

Owing to symmetry in a three-core cable, we can write:

$$K_{1-2} = K_{1-3} = K_{2-3} = K,$$
$$\text{and } K_{1-s} = K_{2-s} = K_{3-s} = S.$$

Now, if 2 and 3 be earthed, as also the sheath, we have:

$$Q_1 = (2K + S) V_1 \text{.........(C)}$$

If 2 and 3 be connected together, but not earthed (the sheath being earthed), and if they together have an equal and opposite charge to that on 1, we have:

$$Q_1 = (2K + S)V_1 - 2KV_2$$
$$Q_2 = (K + S)V_2 - KV_1 = -\frac{Q_1}{2}.$$

$$\therefore V_2 = -\frac{V_1}{2}, \text{and } Q_1 = (2K + \tfrac{2}{3}S)(V_1 - V_2).\text{(D)}$$

Lastly, if 3 be left insulated without charge, and if the charge on 2 be equal and opposite to that on 1, we have:

$$Q_1 = (2K + S)V_1 - K(V_2 + V_3),$$
$$V_2 = - V_1,$$
$$\text{and } O = (2K + S)V_3 - KV_1 - KV_2, \textit{i.e. } V_3 = O.$$

This gives:

$$Q_1 = (3K + S)V_1 = \left(\frac{3}{2}K + \frac{S}{2}\right)(V_1 - V_2).\text{(E)}$$

If, therefore, we measure Q and the potential difference in any two of these cases, we have all particulars necessary for the determination of the capacity constants of the cable.

Reference is made to tests on cables for the Central London Railway, where the figures per mile were as follows:—

1. From one core to other two cores + lead sheath = 0·38 mfd.
2. From one core to other two cores, sheath disconnected and earthed = 0·32 mfd.
3. From one core to one other core, third core insulated, sheath disconnected and earthed = 0·23 mfd.

$$\text{By test (1) } 2K + S = 0{\cdot}38,$$
$$\text{,, ,, (2) } 2K + \tfrac{2}{3}S = 0{\cdot}32;$$

$\therefore$ S = 0·18 and K = 0·1, and by test (3) $\frac{3}{2}K + \frac{S}{2}$ = 0·24 against 0·23 actually measured.

A three-phase △ capacity, as shown in

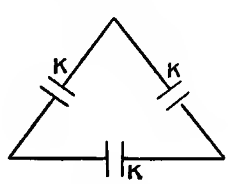


Fig. 2

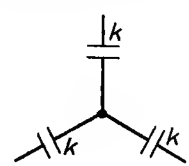


Fig. 3

fig. 2, will take the same capacity current per live wire as a Y capacity, as in fig. 3 (0·48 mf), if $K = \frac{k}{3}$, and the capacity constants of a cable can be treated as if they were capacities connected, as in fig. 3, where the centre point is the lead sheath. The above-mentioned Central London cable is therefore equivalent to a Y capacity of 0·48 mfd per leg per mile.

The capacity of a single overhead wire with earth return in mfd per mile length is:

$$\frac{0{\cdot}03883}{\log \frac{4h'}{d}}$$

where h is height above ground and d is diameter of conductor, both in the same units.

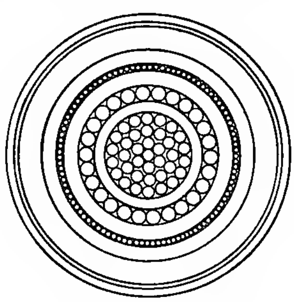
The capacity of two parallel bare aerial wires in mfd per mile length is:

$$\frac{0{\cdot}01942}{\log \frac{D'}{r}}$$

where D is distance apart from centre to centre, and r is radius of the wire, both in the same units.

(Ref. M. B. Field, 'Resonance in Electric Circuits', Journ. I.E.E., vol. xxxii, Feb., 1903; 'Electrical Engineers' Pocket-book', Foster.)

Cable, Concentric, a cable in which two or more cores are arranged concentrically



Triple Concentric Cable

(see fig.). Concentric cables are often used in connection with cc systems, and are either two-core, positive and negative, or three-core, positive, negative, and neutral, the neutral being, as a rule, of less area (frequently one-half) than either the positive or negative. Concentric cables with three cores are termed *triple concentric cables*. Concentric cables can also be used with single-phase systems, but it is not desirable to use them with three-phase, owing to the fact that the three cores are not symmetrical one with another, and that consequently the inductive effects are not equal in the three cores, and the three phases are rendered unsymmetrical. (Ref. 'Distribution of Electrical Energy', J. F. C. Snell; 'Central Station Electricity Supply', Gay and Yeaman.)

['*Concentric Cable*, a cable consisting of two or more separate conductors arranged concentrically with insulation between them. Three conductors so arranged form a triple concentric cable. The external conductor should be called *external*, and not *outer*, in order to avoid confusion with the outer conductors of a three-wire system.'—I.E.C.]

Cable, Dry-core, cable for telephone or similar purposes, consisting of a number of conductors insulated from each other by paper, the whole being lightly braided with cotton, and finally covered with vulcanised rubber and waterproof tape if for aerial use, or with lead if for use underground. Each length of the cable has to permit of the free passage of air through it, while the covering has to be absolutely moisture-proof. In some cases as many as 306 pairs of conductors are included in a single cable. Paper is chosen as an insulator, not only on account of its cheapness, but also because of its low specific inductive capacity, an important consideration in telephone working. See CABLE, AIR-SPACE. (Ref. 'Modern Electric Practice', vol. vi.)

Cable, Duplex, aerial cable, with double braiding or covering, generally compounded, that is, impregnated with or treated with a special compound.

Cable, Equalising. See EQUALISING BARS OR CABLES.

Cable, Flexible, cable the core of which consists of a large number of very fine wires, and can therefore be bent in any direction as desired. Flexible cable is often used to form the connections between the movable brush system of a dynamo or motor and the fixed terminals of the machine; also, suitably protected with flexible armouring, for the connection between movable jib cranes and the plug boxes at the side of the quay or wharf where the cranes work. But the most general use of flexible cable is as connection and support for single incandescent lamps or small groups of incandescent lamps forming a single fitting. In this case the conductor generally consists of from 25 to 225 No. 40 S.W.G. (0·122 mm diameter) wires, and the go and return cables, suitably insulated, are bound together to form what is termed *Twin Flexible Cable*, or, shortly, *Twin Flexible*, or, more shortly still, *Flexible*. Flexible connections for dynamo machines consist, as a rule, of a number of wires of No. 25 S.W.G. (0·508 mm diameter), or thereabouts. (Ref. 'The Internal Wiring of Buildings', H. M. Leaf.)

Cable, Graded.—In underground cables for very high pressures the insulation, if homogeneous throughout, would have to be of very great thickness in order to have sufficient dielectric strength. By employing material of high specific inductive capacity close to the conductor, and material of lower specific inductive capacity toward the outside, *i.e.* by *grading* the insulation, a considerably less total thickness affords equally high dielectric strength.

Cable, Heating of, the rise in temperature of a cable due to the heating effect of the current flowing through it. In this country insulated wires and cables for indoor wiring are generally chosen of such size that the current density does not exceed 1000 amp per sq in of conductor. This is a rough-and-ready rule which, though widely employed, and indeed insisted on by many insurance offices, corporation engineers, &c., gives in the smaller sizes of cables, say below 0·2 sq in (127 sq mm) in area, a larger cable than heating considerations alone require, and a smaller cable for larger areas. In some cases a table prepared by the Institution of Electrical Engineers is worked to. This table is based on the assumption that the cables are run in casing or tubing, and that the highest temperature to which they are subjected must not exceed 55° C. when rubber insulation is employed, or 76° C. with paper or fibre insulation. The table deals with areas up to 1 sq in (645 sq mm), for which the maximum allowable currents are given as 750 amp for either class of insulation. Uninsulated cables and cables suspended in free air will have a smaller rise of temperature for a given current, and, further, as a rule, a higher temperature is permissible. In fact in such cases the area is generally determined rather by considerations of pressure drop and mechanical strength than of heating.

Very little accurate information is available concerning the heating of underground cables, whether laid direct in the ground, or in solid bitumen, or free in ducts. The problem is naturally a complicated one, and the exact rise of temperature will depend upon the thickness of the insulation, of the lead covering, of the number of cables lying together and their exact distance apart, the facilities for conduction and radiation, &c., but it may be stated that for a rise of 25° C. an underground cable with a core section of ½ or ¾ sq in may be worked at a density of 700 or 800 amp per sq in. (Ref. 'Conductors for Electrical Distribution', F. A. C. Perrine; 'Electric Light Cables', Stuart A. Russell; 'Electrical Transmission of Energy', Abbott; I.E.E., 'General Rules of Wiring for the Supply of Electrical Energy'; 'Data Relating to Electric Conductors and Cables', H. W. Fisher, Trans.Am.I.E.E., June, 1905.)

Cable, Jute-insulated. See CABLE, UNDERGROUND.

Cable, Paper-insulated, cable in which the insulation of the conductor consists of paper. The paper, which is made in rolls from about 45 to 60 cm wide, is cut into disks from 3 mm to 75 mm wide. The disks are then put on what are termed taping heads, which are revolved round the conductor, and so form spirals of paper one above another, each layer covering the joint of the layer below. In the cases of small wires there may only be two or three layers of paper, while high-tension cables may have 100 layers. After they have been removed the cables are thoroughly dried in a vacuum, and afterwards placed in a bath of hot compound the exact composition of which varies with the maker, but consists essentially of oil mixed with resin or some bituminous substance. The cables are allowed to soak for a time in this material. The compound renders the cable more moisture-resisting, and increases the strength of the insulation. Finally the cable receives a covering, generally of lead, to protect it against moisture, since, even when impregnated, the insulation is very sensitive to damp. See also CABLE, UNDERGROUND. (Ref. 'Distribution of Electrical Energy', J. F. C. Snell; 'Central Electrical Stations', C. H. Wordingham; M. O'Gorman, 'Electrician Primers', 2nd ed., 1906.)

Cable, Paying-out, running-out submarine cable from a cable ship; also, on land; unwinding cable from a cable drum. (Ref. 'Submarine Cable Laying and Repairing', Wilkinson.)

Cable, Pressed Stranded, as the name implies, a conductor made up of a number of small wires woven together and pressed up to any convenient shape. The advantage of this construction is that a conductor may be obtained which, notwithstanding its large section, is nevertheless quite flexible, and that the more or less imperfect contact between the various strands ensures a minimum of eddy-current losses.

ENAMELLED PRESSED STRANDED CABLE, a form of pressed stranded cable in which each strand has been covered with a flexible enamel which does not crack or is not easily displaced. The enamel thus completely insulates one strand from another, and reduces eddy-current losses in the conductor to a negligible quantity.

Cable, Rubber, cables insulated with indiarubber. Such cables are generally used for the internal wiring of buildings, as it has been found that, if laid in the ground or otherwise subjected to moisture, the rubber fails in time. Rubber-insulated cables can, of course, be lead covered, but they are then more expensive than paper-insulated cables similarly treated, and the use of the latter has therefore become more general for underground working where the runs are long and uninterrupted.

Rubber cables are made *single-core*, *twin*, *concentric*, *three-core*, and *multi-core*; and the conductors are almost invariably of soft, high-conductivity copper, though where extra mechanical strength is required, as, for instance, for 30 or 40 yd spans hard-drawn copper has to be employed. In the latter case the conductivity is slightly decreased.

Stranded conductors are generally used for all except the smallest sizes, in order to give flexibility. The number of strands employed are 3, 7, 19, 37, 61, 91, and 127, the seven strands consisting of 6 round 1, the nineteen strands of 12 round 7, and so on. Where still greater flexibility is required, as in the case of the connecting leads to the brushes of dynamos or motors, a large number of small wires are used. (See CABLE, FLEXIBLE.)

Of the indiarubber employed, the best comes from the State of Para in Brazil. All rubber as received by the manufacturer contains impurities, and these have to be removed by washing and passing through specially shaped rolls. When dry, the rubber is made into sheets, which in turn are cut into strips, and these are wound round the wires or strands, which have first to receive a coating of tin to protect them from any possible chemical action due to the presence of sulphur. The covering of pure rubber gives a high insulation resistance to the cable, but if unprotected would rapidly deteriorate owing to the action of the atmosphere, and hence the outer covering of rubber is *vulcanised*—that is to say, is mixed with sulphur and subjected to heat. For mechanical protection the vulcanised rubber is covered with a layer of special tape, and finally the cable is passed through a *braiding* machine which gives it a braided covering of jute, hemp, or cotton. The braiding is passed through a bath of wax or preservative compound to prevent its decay in the process of time.

If the cable is to be subjected to very rough usage, as, for example, if it is to be used to convey current from a quarry plug-box to a jib crane, it is generally given a flexible covering of steel or other wire.

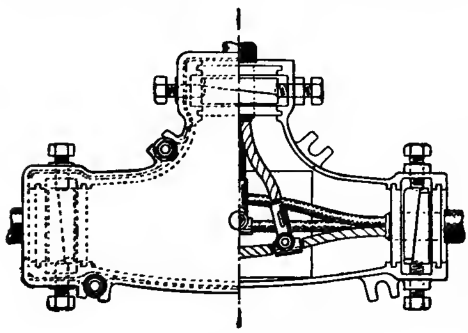
Rubber-covered cables are made of various degrees of insulation resistance, the more usual standards being 300 megohms, 600 megohms, and 2500 megohms per mile. The insulation tests are generally taken after twenty-four hours' immersion in water at 60° F. (15·5° C), the reading itself being observed after one minute's electrification (*i.e.* application of the testing pressure). The smaller sizes of each class generally give a much higher insulation resistance than that indicated by the standard.

A number of cable makers in this country have recently combined to form a *Cable Makers' Association*, and the various members manufacture cables to fixed standard sizes and grades. See CABLE, ASSOCIATION; RUBBER; CABLE, UNDERGROUND. (Ref. 'Conductors for Electrical Distribution', F. A. C. Perrine; 'Modern Electric Practice', vols. ii, iii, and iv.)

Cable, Screened. See SCREENED CONDUCTOR.

Cable, Service, a cable laid from public or general supply mains to the premises of individual consumers.

In most Provisional Orders granted to suppliers of electric current (undertakers, as they are rather unfortunately termed in official documents) it is stipulated that a supply must be granted to any consumer demanding it, provided that his premises are within 50 m of a *distribution main*, or *distributor*, as it is called. The consumer may be called upon to pay for any cable on his own premises, or beyond 20 m from the *distributor*; apart from this, the undertakers have to supply and lay service cables and to provide a main fuse in each conductor, the fuses to be arranged in a locked or sealed receptacle or receptacles. All service cables and fuses supplied by the undertaker remain his property, and he has to maintain them. He also has to declare the pressure at which he will supply current to the *consumer's terminals*, and must not depart from this pressure more than 4 per cent, under the penalty of a fine on conviction. The consumer on his part must, if required, give one month's notice of demand for supply or of increase in demand, and must pay for alterations to service cables due to alteration of demand.



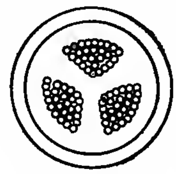
Service Box for Three-core Cable

In many populous districts *service boxes* are provided on the distributors every 25 m or so, and service cables run back to them; in other cases service cables are connected straight on to the distributors as required. A service box for a three-core cable is shown in the figure. Various classes of underground cable can be used as *service leads*, but concentric armoured cable laid straight in the ground is perhaps as widely employed as any. 7/16 is generally the smallest cable employed, and 19/18, 19/16, and 19/14 are favourite sizes. In many cases a standard size of service is employed for all requirements, and current for not more than, say, 100 16-cp lamps, or the equivalent, is permitted to be taken through any single *service main.* If more lights have to be supplied a second service cable is provided. (Ref. 'Central Station Electricity Supply', Gay and Yeaman.)

Cable, Suspending Wire of, a wire or strand of wires stretched between supports, from which an insulated cable is suspended at intervals by means of short slings. An insulated copper cable, if of any but small size, is not of sufficient strength to bear straining up properly, and therefore a suspension wire is provided. The suspension wire is generally of steel and the *slings* are generally of leather.

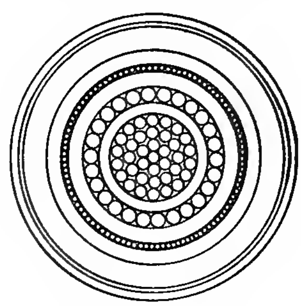
Cable, Telephone. See TELEPHONE CABLE.

Cable, Three-core, a cable containing three cores or separate conductors insulated from one another and from the outside of the cable. Such cables are used for three-phase supply, in which case the conductors are all of the same area (see fig.); and for three-wire supply, in which case the neutral is generally of smaller size than either of the outers, most frequently of half the area. (Ref. 'Distribution of Electrical Energy', J. F. C. Snell; also 'Conductors for Electrical Distribution', F. A. C. Perrine.)



Three-core Cable (3-phase)

Cable, Triple Concentric, concentric cable having three concentric conductors (see fig.). Cable of this type is largely used in three-wire supply systems, the neutral conductor having half the area of either of the outers. Triple concentric cable cannot be satisfactorily employed in three-phase systems owing to the three cores not being symmetrically arranged in relation to one another, their reactive effects on one another consequently being unequal. (Ref. 'Distribution of Electrical Energy', Snell.)



Triple Concentric Cable

Cable, Twin. See CONDUCTOR, TWIN.

Cable, Underground, a cable laid underground for carrying an electric current.

The conductor is generally of stranded copper wire, and stranded conductors of special shapes are frequently used with a view to keeping down the size and consequently the cost of the cable; the special shape can be obtained either by taking a stranded core of circular section and hammering or rolling it to the desired section, or by building up the conductor to the proper shape by a suitable choice of wires. (See illustration at CABLE, THREE-CORE.)

The chief types of cable met with are (with reference to their cores), *single, twin, concentric, two-phase with common return, triple concentric, three core, and four core for a three-phase supply with neutral.* It should be noted that single cores should not be used for ac if there is metal sheathing on the cable, further that a triple concentric is not suitable for three-phase currents owing to the fact that the three cores are not symmetrical one with another, and therefore that their inductive effects on one another are different. If a cable is worked at a pressure of more than 3000 volts, the Board of Trade requires arrangements to be made to prevent either the surrounding earth or a neighbouring conductor being charged in the event of a leakage from the cable. Where a number of lead-covered cables run side by side, the requirement will be met by bonding the lead covers together at frequent intervals, but, as a rule, either a thin copper sheathing is put under the lead and in direct contact with it, or a galvanised iron or steel wire sheathing is placed over, and in contact with, the lead.

INSULATION.—*The insulation of an underground cable* generally consists of impregnated paper, impregnated jute, or vulcanised bitumen.

PAPER-INSULATED CABLES are the most commonly met with. The paper is manufactured in rolls 45 to 60 cm wide, which are cut into disks from 3 mm to 75 mm wide; the disks are mounted on what are called taping heads, and these are revolved round the conductor and so lay on the paper in spiral layers, which are so distanced that one layer covers the joint in the layer underneath. In the case of some small wires, only two or three layers are required, while a hundred layers may be used on an extra h pr cable. After the winding on of the paper has been completed, the cable is thoroughly dried and then plunged into a hot compound, consisting generally of oil mixed with resin or some bituminous substance, in which it is allowed to soak until it is thoroughly impregnated and so rendered less pervious to moisture and better able to stand electrical stresses. A paper-insulated cable, however, is useless unless covered with a waterproof coating, which generally takes the form of a lead sheathing, which is pressed on from special hot-lead presses; and finally a serving of jute or hemp is sometimes laid over the lead, and a sheathing of steel wire or an armouring of steel tape applied, which in turn may be again served with jute or hemp, well tarred and compounded.

The steel wire used in sheathing is galvanised to protect it against rust, and is applied to the cables by machines similar to those employed in stranding the conductor, the outer serving being applied at the same time. The wires may be of any size from, say, 72 mils (1·83 mm) up to $\frac{3}{8}$ in. (9·5 mm) in diameter, depending upon the requirements of the case. Steel-tape armouring is applied in two layers, the outer layer covering the joint in the lower one; and it should be noted that whereas steel-wire sheathing gives considerable tensile strength and but moderate protection against labourers with picks, steel-tape armouring offers the reverse qualities. The cables, after serving, are covered with a mixture of chalk and water to prevent the turns from sticking together on the drums on which they are coiled.

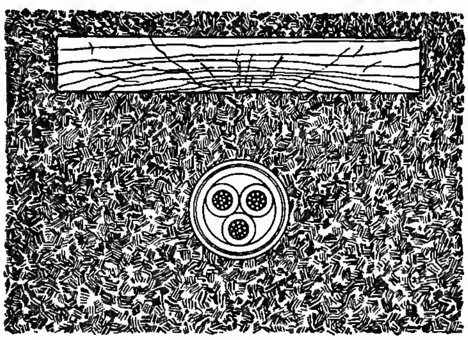
The insulation resistance of a paper-insulated cable may vary from 50 to 100 megohms per mile, depending upon the size and purpose of the cable.

IMPREGNATED JUTE CABLES are treated in somewhat the same way as paper-insulated cables: the jute is laid on spirally with not less than two layers, in opposite directions, and the cables are dried, impregnated, lead-covered, and, if desired, armoured. Such cables are used for low-tension work, and for pressures up to, say, 2500 volts.

VULCANISED BITUMEN is a compound material consisting chiefly of bitumen. It is applied to the conductors either as tape or by pressure through a die, after which it is heated to consolidate it and render it uniform. *Bitumen-insulated cables* are waterproof, and therefore do not require a lead covering; they are, however, protected mechanically by tapes and braiding, or by steel-wire sheathing or steel-tape armouring. See BITUMEN.

Indiarubber is now but rarely used *for the* *insulation of underground cables*, except pilot wires. When it is so used, it should be protected against moisture, and other deteriorating influences, by lead covering, otherwise the rubber is apt to perish in time. See CABLE, RUBBER; also RUBBER.

Underground cables are laid direct in the ground, or *solid* in troughing (see SOLID SYSTEM OF CABLE LAYING), or are drawn into ducts. When laid direct in the ground, steel-armoured cables are generally employed, and these should be covered with rough boarding or a layer of bricks where the ground is liable to be disturbed, in order that workmen may have warning when on the route of the cables. A three-core armoured cable, laid underground in this



Underground Cable

manner, is shown in the figure. For cables laid solid, see SOLID SYSTEM OF CABLE LAYING, and for cables drawn into ducts, see CONDUIT, UNDERGROUND. [F. W.]

Cable, Varnished Cambric. See VARNISHED CAMBRIC CABLE.

Cable and Bar Windings. See WINDINGS, CABLE AND BAR.

Cable Bearer. See CATENARY SUSPENSION.

Cable Box. See BOX, CABLE.

Cable-charging Gear, apparatus for gradually applying electrical pressure to a cable. If a feeder cable be suddenly switched on to or off from a high-potential bus-bar, there is a possibility of greatly increased electrical pressures being caused. The exact values of these pressures depend upon the relations of the capacity and self-induction of the circuit, and hence in some h pr alternating systems cable-charging gear is employed to gradually raise the pressure on an incoming feeder, or to gradually reduce it on a feeder that is about to be switched off. The best form of charging gear consists of a water resistance which is inserted in the feeder and gradually reduced in ohmic value, say by pushing down plunger contacts until full pressure is on the feeder. The charging device can then be short-circuited and cut out of circuit, ready for use on another feeder. Motor generators that are speeded up to give an increasing pressure until full pressure is reached have also been used, but these are liable to do more harm than good, since at some definite speed below synchronism one of the superimposed waves on the main alternating wave may encounter just the conditions necessary to give resonance, and dangerously high pressures will result. If a motor generator is used, it is preferable to first run it up to full speed with the generator side unexcited, and then gradually raise the excitation on the generator. A non-inductive resistance, such as the water-resistance referred to above, affords much the better means. A transformer, with the primary in series with the incoming cable, is also sometimes employed, the gradual increase of pressure on the cable being effected by gradually short-circuiting the secondary of the transformer; but this method is at best a doubtful one, since it provides a varying inductance in series with a capacity, a condition very likely to be productive of resonance and consequent rises of pressure.

Since the introduction of the oil-break switch, the risk of dangerous rises of pressure on switching off a cable has been removed, owing to a property of the oil, in consequence of which the arc is broken at the instant that the current-wave passes through the zero point, and, as the danger of serious rises of pressure on switching on is not very great, the use of cable-charging devices is not by any means universal. Very many generating stations, both in this country and in America, operate satisfactorily without them. [F. W.]

(Ref. 'Electricity Control', Andrews; M. B. Field, 'Journ.I.E.E.', vol. xxxii, 1903.)

Cable Core. See CORE, CABLE.

Cable Coupling. See COUPLING, CABLE.

Cable Drum, a large reel, generally of wood, upon which cable is wound for purposes of transport or storage.

Cable Feeder. See FEEDER.

Cable Grip, an arrangement for gripping a cable, and thereby enabling it to be pulled through a pipe or conduit. (Ref.

'Distribution of Electrical Energy', J. F. C. Snell.)

Cable Joint, High-pressure. See HIGH-PRESSURE CABLE JOINT.

Cable Laying, Solid System of. See SOLID SYSTEM OF CABLE LAYING.

Cable Makers' Association. See CABLE, ASSOCIATION.

Cable Sheathing. See CABLE.

Cable Ship, a ship specially arranged for the laying or repairing of submarine cables. (Ref. 'Submarine Cable Laying and Repairing', H. D. Wilkinson.)

Cable Subway. See SUBWAY.

Cable Tank, (1) a tank in which insulated cable is immersed in water for the purpose of making measurements of the insulation resistance; (2) a tank on a cable ship in which a submarine cable is coiled prior to being laid.

Cable Troughing.—On the *solid* system of cable laying, the cables are laid in troughs of wood, iron, or earthenware, which are filled up so as to enclose the cable completely with melted compound consisting mainly or wholly of bitumen. The troughing is then covered with tiles, or with covers of the same material as the troughing.

Cableway, Electric. See CRANE, ELECTRIC.

Cadmium (chemical symbol, Cd), a metal resembling zinc. The specific resistance of pure cadmium at 0° C., as determined by Dewar and Fleming, is 100 microhms per cu cm. Its resistance increases 0·42 of 1 per cent per degree Centigrade increase in temperature. Its specific gravity is 8·6. The melting-point of pure cadmium is 320° C.

Cadmium Standard Cell. See 'Weston Cadmium Cell' under CELL, STANDARD.

Cage, Crane. See CRANE, ELECTRIC.

Calibrate, to compare the readings of an instrument with those of a standard, or to deduce the exact meaning of any reading by calculation. The result may be expressed in the form of a curve, if the instrument scale is already divided, or the points representing even values may be marked on a blank scale.

Calibration, the relation between the reading of an instrument and the respective true values of the quantities measured, expressed either in the form of a table or of a curve.

When the calibration may be deduced directly from first principles and the dimensions of the instrument, the calibration is said to be *absolute.* When it is simply a comparison of two instruments, one of which is taken as a standard, the calibration is said to be *relative.*

['*Calibration* of a measuring instrument. The determination of the value of the divisions of the scale of an instrument by comparison with a standard, or by some fresh determination.'—I.E.C.]

Callender's Recording Wheatstone Bridge or Potentiometer. See BRIDGES.

Callender-Webber Conduit. See CONDUIT, UNDERGROUND.

Calling, Automatic. See AUTOMATIC CALLING.

Calling Plug, the connector used by the exchange operator in calling a telephone subscriber.

Calorie.—

['(*a*) The calorie or gramme calorie (also called the small calorie) is the quantity of heat required to raise the temperature of 1 g of water 1° C. (*b*) The Kilo Calorie (also called the Great Calorie) is 1000 calories, and is the quantity of heat required to raise the temperature of 1 kg of water 1° C.

Note.—The value of the calorie depends to some extent on the temperature at which the water is taken, and on the scale of the thermometer employed. The hydrogen thermometer is usually adopted as the standard, and the temperature selected is generally 15° C. or 20° C., or the mean 0° C.—100° C.'—I.E.C.]

Calorific Value.—The calorific value of a fuel is the amount of energy obtainable in the form of heat by the combustion of a given weight of the fuel. In electrical engineering calculations the most convenient form in which to express the calorific value of a fuel is in kelvins (*i.e.* kw hr) per ton. A representative value for good Welsh coal is 8700 kelvins per ton. For the convenience of those engineers who are at present more accustomed to deal with calorific values in British Thermal Units, it may be stated that 1 kelvin (or kw hr) is equal to 3411 British Thermal Units, and that a calorific value of 10,000 kelvins per ton corresponds to a calorific value of 15,500 British Thermal Units per lb.

Calorific Value of a Fuel, the amount of heat energy which, in electrical engineering, is preferably expressed in kelvins per ton, which becomes available by the complete combustion of the fuel.

Cambric for Insulating Purposes.—For insulating purposes the treatment a cambric is to receive will to some extent influence its selection. Whether for impregnating or varnishing, it should be evenly woven and uniform in thickness, with not too great an elongation under tension. For impregnating, it should not be too closely woven, and should preferably be unbleached. For varnishing, a fairly closely-woven cloth is desirable, whilst an entire absence of nap is almost essential. All moisture should be thoroughly dried out before treatment.

VARNISHED CAMBRIC.—The cambric employed for this purpose must be evenly woven, uniform in thickness, and free from nap. The varnish used and its method of application must be such as to produce a smooth, uniform, flexible coat. See VARNISHED CAMBRIC TUBE; VARNISHED CAMBRIC CABLE; IMPREGNATED INSULATING MATERIALS.

Canal Traction, Electric, a method of hauling barges on canals by means of electrical tractors running along the tow path or by some alternative electrical means. Various systems have been devised, with and without rails; in the *Wood system* a single rail is used, consisting of an I girder supported on short columns; the motor is suspended below the rail, and drives the wheels or rollers through spur gearing. There are four wheels, two above and two below the rail, which they grip tightly by virtue of a system of levers, in proportion to the tension of the hauling rope, thus securing the necessary adhesion. A driver is carried on the tractor, which he controls. Power to drive the machine is derived from an overhead trolley wire, the current returning through the rail. This type of electric canal tractor is illustrated on the plate which is given as frontispiece.

Canalisation, Underground. See UNDERGROUND CANALISATION.

Candle-foot.—The candle-foot is the unit of illumination when the unit of intensity is the light of a candle and the unit of distance the foot.

An intensity of one candle-foot is produced by the light from a standard candle at 1 ft from it, in the same horizontal plane as the flame. At 2 ft distance the intensity is $\frac{1}{4}$ candle-foot, at 10 ft $\frac{1}{100}$ candle-foot. A 32-candle electric lamp at 6 ft produces an intensity of $\frac{32}{36}$ candle-feet.

[‘*Candle-foot*, the illumination produced by one cp falling perpendicularly on a surface at a distance of 1 ft.’—I.E.C.]

Candle-meter.—This is the unit of illumination on the metric system, and since 1 m = 3·1 ft, 1 candle meter = $\frac{1}{(3{\cdot}1)^2}$ candle-foot. See also CANDLE-FOOT.

Candle Power (preferable abbreviation cp).—The usual unit for the measurement of the intensity of a source of light is the light emitted by a standard candle.

It is defined as the intensity of the light of a candle of certain composition, length, and weight, when burning at the rate of 120 grains (7·8 g) per hour (Stine, p. 115, *et seq*).

In practice, owing to the difficulties of realising all the conditions required to make the intensity of the light a reproducible quantity, many other standards have been brought into use, of which the most important are: in Britain, the *Vernon-Harcourt pentane lamp* of 10 nominal candles; in France, the *Carcel lamp*, practically equal to the above; and in Germany, the *Hefner standard* of about 0·90 of an *English nominal candle.* See STANDARD OF LIGHT.

[‘*Candle power*, the luminous intensity, or illuminating power, of a source of light.’—I.E.C.]

MEAN CONICAL CANDLE POWER OR MEAN ZONAL CANDLE POWER.—The mean of the cp in all directions making a given angle θ with the equatorial plane of a lamp, is called the mean conical candle power at the angle θ. All these directions lie on a cone the vertex of which is the centre of the lamp and the axis of which coincides with that of the lamp. The semi-vertical angle is $90° - \theta$. If the mean conical cp at certain angles be measured, the average of the results is the mean spherical cp.

MEAN HEMISPHERICAL CANDLE POWER.—If there be drawn from a source equally in all directions either below or above the equatorial plane, lines whose lengths are proportional to the cp in these directions, then the mean value of the lengths either above or below is the mean hemispherical cp of the upper or lower hemisphere respectively.

MEAN SPHERICAL CANDLE POWER.—If there be drawn from a source equally in all directions lines whose lengths are proportional to the cp in these directions, then the mean value of the lengths of all these lines is the mean spherical cp. (Ref. Russell, Journ. I.E.E., vol. xxxii, p. 631.)

MEAN HORIZONTAL CANDLE POWER.—If from a source there be drawn lines equally in all directions in a plane, and their lengths be made proportional to the cp in these directions, then the sum of all these lengths, divided by their number, gives the mean cp in that plane. When the axis of the lamp is vertical, the mean cp in the horizontal plane is called the mean horizontal cp. (Ref. 'Mean Horizontal and Mean Spherical Candle Power', Russell, Journ. I.E.E., vol. xxxii, p. 631.)

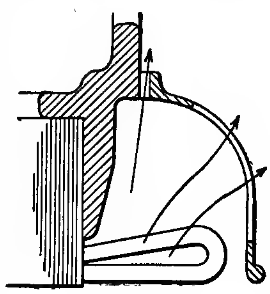
PARLIAMENTARY CANDLE, BRITISH CANDLE, or SPERM CANDLE, the light given out by a sperm candle when burning 120 grains per hour. The candles must weigh 'six to the lb'.

Canopy Switch. See SWITCH, CANOPY.

Canvas Belts. See GEARING FOR ELECTRIC MOTORS.

Caoutchouc, the South American name for rubber in its raw state. See RUBBER.

Cap, Protection.—Large machines which do not have end shields, but whose bearings are constructed in separate pedestals, are usually provided with quadrant-shaped castings which are bolted to the frame or housing of the machine and which protect the windings from damage or prevent the attendants from coming into accidental contact (see fig.). These castings are known as protection caps, and are usually of an open design in order to allow an easy escape of the hot air from the stator windings.



Protection Cap

Cap, Winding.—When the separate bars of a bar winding are sweated up together at the ends of the connections, some protection is required against the dust, which will collect and so produce leakage and ultimately short circuits. For this purpose caps, usually of varnished cambric, are made, which may be slipped over the soldered joint and then tied on with cord.

Cap of Incandescent Lamp.—The cap of an electric glow lamp serves to provide convenient means for the current to flow to the filament of the lamp from the contact in the holder. This cap consists essentially of a brass ring filled with plaster of Paris in which the leading-in wires are embedded, finally terminating in two insulated conducting surfaces, into which current flows from the holder. The cap may be designed either for the *screw* or *bayonet* holder. See LAMP HOLDERS.

EDISON SCREW CAP.—This form of cap is shown in fig. 1. One of the leading-in wires from the lamp is connected with an outer threaded tube T, and the other is connected with a raised brass contact-stud P at the base of the cap, which is insulated from the outer tube and held in position by plaster of Paris.

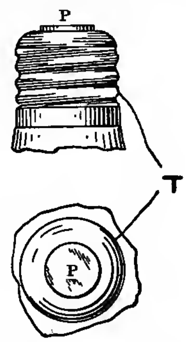


Fig. 1.—Edison Screw Cap

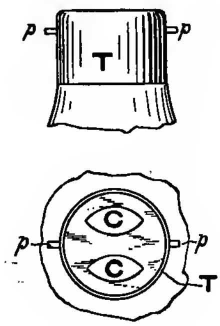


Fig. 2.—Bayonet Cap

THE 'BAYONET' CAP is an attachment to the base of an incandescent glow lamp, and serves to conveniently convey the current from the lamp holder, connected with the source of electric pressure, to the filament in the lamp (see fig. 2). The cap consists essentially of a brass collar T, in which two diametrically opposite pins *p p* are mounted. Flush with the top of the brass collar are two brass contacts C C, which are held in position and insulated from one another by plaster of Paris. The leading-in wires of the lamp, which are themselves connected with the filament, are attached to these two contacts. When the lamp is placed in the bayonet holder, the two contacts are themselves brought into contact with two brass plungers in the holder, which are in turn in connection with the source of electric pressure.

Capacity. — 1. A term indicating the quantity of electricity which will be contained by two insulated conductors when a given difference of potential is maintained between them. This may be termed the *static capacity*.

2. The capacity of a conductor for carrying an electric current when sustaining a given temperature rise.

3. The capacity of an accumulator for storing electricity.

4. The *rated capacity* (see RATING, NORMAL) and the *overload capacity* (which see) of an electric machine.

['*Capacity* (*a*) of an accumulator. The quantity of electricity in amp hr which may be taken from a cell at a given rate of discharge. (*b*) Of a condenser. The quantity of electricity which must be imparted to a condenser, or to a conductor acting as a condenser, in order to raise its potential from zero to unity. (*c*) Of a machine or of a generating station. This use of the word 'capacity' is not recommended. The term *rating* should be used.'—I.E.C.]

Capacity, Carrying. — The carrying capacity of a conductor, expressed in amp, is that current which will give rise to the maximum permissible loss of potential, or which will raise the conductor to its safe limit of temperature.

Capacity, Carrying, of Cable. See CABLE, HEATING OF.

Capacity, Dielectric. See DIELECTRIC CONSTANT.

Capacity, Electromagnetic. — The electromagnetic unit of capacity is that capacity which, when charged to unit potential, will contain a charge which is equal to the amount of electricity passing per sec in a unit current. The practical unit is the farad, which is 10^{-9} of the cgs electromagnetic unit. To charge a farad to 1 volt requires 1 coulomb, *i.e.* the quantity of electricity flowing per sec when the current is 1 amp. The farad is too large for most purposes, and the mfd (*i.e.* the one-millionth of a farad) is generally used. [J. E-M.]

Capacity, Electrostatic.—This is not, in the ordinary sense of the word, an absolute quantity, like that of a pint pot, but is defined as the quantity of electricity on a conductor when it is at unit pd from its surroundings. Thus the *capacity of a condenser* is equal numerically to the charge on either plate when their difference of potential is unity. The *capacity of a sphere* at a distance from other conductors is, in electrostatic measure, equal to its radius in cm. The *capacity of a plate condenser* is proportional to its area, and inversely proportional to the thickness of the dielectric between the plates, a correction being required unless the thickness of dielectric is very small as compared with the dimensions of the plates. (See also CAPACITY, ELECTROMAGNETIC.) The capacity of a condenser is also proportional to the specific inductive capacity of the dielectric between the plates of the condenser. [J. E-M.]

Capacity, Instantaneous. See CAPACITY, ELECTROSTATIC.

Capacity, Measuring, Gott's Method of. See GOTT'S METHOD OF MEASURING CAPACITY.

Capacity, Polarisation. See POLARISATION CAPACITY.

Capacity, Specific Inductive. See DIELECTRIC CONSTANT.

Capacity, Unit of. See CAPACITY, ELECTROMAGNETIC; and CAPACITY, ELECTROSTATIC.

Capacity and Self-induction of Telegraph Lines. See TELEGRAPH LINES, CAPACITY AND SELF-INDUCTION OF.

Capacity Area (in wireless telegraphy), a large conducting surface, whether composed of sheet metal or a network of wires.

Capacity Current, an ac which charges a condenser, or something equivalent thereto, such as a system of cables. A capacity current is practically wattless (see CURRENT, WATTLESS), and its phase is a quarter period in advance of the emf.

Capacity of Cable. See CABLE, CAPACITY OF; CABLE, HEATING OF.

Capacity of Condenser. See CAPACITY, CAPACITY, ELECTROMAGNETIC; and CAPACITY, ELECTROSTATIC.

Capacity of Telegraph Conductor.—Used in two senses: (1) Electrostatic capacity; (2) number of words per minute which can be transmitted. In cable working (2) depends largely on (1), increase of (1) reducing (2). In land lines (1) is usually negligibly small, and (2) is determined by other factors. (1) is much greater in cables than in land lines on posts, because of the much thinner dielectric separating the conductor from surrounding conductors.

Capacity Reactance denotes the quantity, $\frac{1}{2\pi v C}$, where v = frequency and C = capacity in farads. Capacity reactance is measured in ohms, but is opposite in sign to inductive reactance. If a circuit contains resistance, (inductive) reactance, and capacity, its total impedance may be found by combining, at right angles, the difference between the inductive reactance and the capacity reactance with the resistance. See also REACTANCE.

Capillary Electrometer. See ELECTROMETER.

Capital Costs of Electrical Plant. See Central Station for the Generation of Electricity.

Capyt, the trade name of a moulded composition manufactured in several qualities. The better qualities are hard, but inclined to be brittle. They will take a good polish, but soften at a rather low temperature. See also 'Moulded Insulators' under Insulator.

Car, Electric, a railway or tramway car propelled by means of electricity. See also Accumulator Car; Trolley Car; Motor Car.

Car Controller. See Control, Series-parallel, and Rheostatic.

Car Equipment. See Equipment.

Car Heater. See Heater, Electric.

Car Resistance. See Traction, Coefficient of.

Car Wiring, in general the equipment of insulated wires and cables required for power, lighting, heating, and signalling on a car. The power cables are usually made up in sets of suitable lengths, with the necessary taps, and are enclosed in canvas hose. They include the connections between the motors, controllers, resistances, &c., with additional cables to the circuit breakers and trolley.

Carbon (chemical symbol, C).—Carbon is widely employed in the electrical industry for various purposes, such as for the filaments of incandescent lamps, for the 'carbons' of arc lamps (see Carbons, Arc Lamp), for the brushes (see Brushes) of dynamo-electric machinery, for contacts, and also as a resistance material (see Rheostat). As employed in the electrical industry, carbon is generally either in the amorphous form or in the graphitic form, and in these two forms it is designated respectively *carbon* and *graphite.* Carbon is neither soluble nor fusible.

Graphite, as mined from the earth, rarely contains more than 50 per cent of carbon, and it is very expensive to separate this from the equal quantity of earthy and organic impurities. Graphite, as obtained by means of the electric furnace, is practically pure carbon. See also Graphite; Retort Carbon.

Carbon, Retort. See Retort Carbon.

Carbon Bisulphide is a rather heavy liquid, though extremely volatile, and has an objectionable odour. This necessitates very thorough ventilation where carbon bisulphide is employed, and largely restricts its use.

Carbon bisulphide is used as a solvent for rubber and for some compounds used in waterproofing. The hard resins are insoluble in it.

Carbon Brushes. See Brushes.

Carbon Diaphragm, a thin carbon plate forming the vibrating part of a microphone telephone transmitter.

Carbon Regulator. See Regulator, Potential.

Carbon Resistances. See Rheostat.

Carbon Rheostat. See Rheostat.

Carbon Telephone Transmitter. See Microphone.

Carbone Arc Lamp. See Lamp, Arc.

Carbonisation.—When an organic material such as cotton, wood, or hard rubber is heated sufficiently, it loses its more volatile constituents, and the carbon remains behind in a free state. The occurrence is of importance to electrical engineers, since it frequently happens to insulating materials if the apparatus of which they form a part is operated for a long time at an unduly high temperature. The carbonised substance ultimately ceases to insulate, and a breakdown results. The overheating may also occur through local heating set up in the insulating material itself, as soon as it begins to conduct. See 'Insulation Breakdown' under Insulator; Insulator Pin; Commutator Insulation, Effect of Oil on.

Carbonised Cloth, a loosely woven calico which is carbonised in a vacuum, and after carbonisation has a considerable spring and resiliency. It is used in the construction of adjustable resistances in the form of a pile of discs or square pieces, which may be compressed by a screw or cam. Compression reduces the resistance of the pile. The range of resistance of a pile of plates 6 cm square and about 15 cm high is from 0·15 to 3·5 ohms. Such a pile will carry a current of 6 amp without overheating, and if smaller currents are used the pressure may be still further reduced so as to increase the resistance.

Carbons, Arc Lamp.

Solid Carbons, carbons which are made throughout of exactly the same homogeneous carbonaceous material.

Cored Carbons.—Carbons are often made in a hollow form, and the central cavity is filled with a softer or more easily volatilised material than the solid outer casing. Such carbons are termed *cored carbons*. The *arc* is more inclined to keep central when cored carbons are employed, and also to strike again more easily when once blown out.

FLAME CARBONS.—Volatile metallic salts are sometimes introduced into the cores of carbons in order to produce *flame arcs* (which see under ARC). Such carbons are termed *flame carbons*.

MINERALISED OR IMPREGNATED CARBONS.—The performance of carbons may be improved by impregnating them with certain metallic salts, which eventually are treated in such a way as to give a metallic deposit throughout. The carbons thus prepared are said to be *mineralised* or *impregnated*.

COAXIAL CARBONS.—In the arc lamp it is customary for the carbons between which the arc is formed to be one above the other, and in alignment, as shown in the diagram. Carbons arranged thus are said to be *coaxial* (see fig. 1).

Fig. 1.—Coaxial Carbons

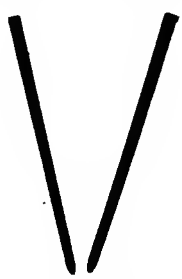


Fig. 2.—Inclined Carbons

INCLINED CARBONS.—Instead of coaxial carbons we may employ carbons sloping to meet one another at a convenient angle, as shown in the diagram. Carbons thus arranged are termed *inclined carbons*.

One advantage of inclined carbons lies in the avoidance of the loss of light resulting from the obstruction of the negative carbon which occurs when coaxial carbons are used (see fig. 2).

ACTINIC CARBONS.—By adding to the carbons suitable metallic salts, carbons can be prepared yielding a spectrum specially rich in ultra-violet light. Such carbons are termed *actinic carbons*. See also ARC; LAMP, ARC. [L. G.]

Carborundum Coherer. See COHERER, CARBORUNDUM.

Carborundum Resistance. See RHEOSTAT.

Carcase of Dynamo, the base casting of the yoke and field magnets of a cc machine. Less frequently it signifies the *stator frame* casting of an ac machine.

['*Carcase*, of a dynamo, alternator, or motor. The assembled pole cores, pole pieces, and yoke or frame.' —I.E.C.]

Carcel Standard of Light. See STANDARD OF LIGHT.

Cardew Hot-wire Voltmeter. See VOLTMETER; VOLTMETER, CARDEW.

Cardew Protective Device. See PROTECTIVE DEVICE, CARDEW.

Carey Foster Bridge. See BRIDGES.

Carrying Capacity. See CAPACITY, CARRYING.

Cartier Hydrometer Scale. See HYDROMETER SCALES.

Cartridge Fuses. See FUSE.

Cascade. See CASCADE MOTOR.

['*Cascade*, (*a*) a series connection of two or more condensers; (*b*) a method of electrically connecting induction motors whereby the induced part of one motor is connected electrically with the inducing part of the other. Also called *Concatenation* and *Tandem*.' —I.E.C.]

Cascade Control. See CASCADE MOTOR.

Cascade Converter. See CONVERTER, CASCADE.

Cascade Motor, a pair of ac motors having their shafts rigidly coupled together mechanically, and connected together electrically as follows. The stator of the first motor is connected to the source of supply; the rotor of the same motor is provided with a polyphase winding, with slip rings and brushes, and is connected with the stator of the second motor. The rotor of the latter is also wound, and is connected with a starting resistance by means of slip rings and brushes. The stator of the second motor is wound for half the normal frequency of the supply current. In operation, when the connections are made as above explained, the combination runs at half the normal speed of the first motor; for higher speeds the second motor is cut out, and runs idly, while the rotor of the first machine is connected with a rheostat and runs at twice the former speed. For regenerative braking from above half speed, the motors are again connected in cascade. This arrangement is used mainly for the purpose of electric traction with three-phase motors. The motors are sometimes said to be *concatenated motors*.

The precise method above described is sometimes termed *cascade single control.* Sometimes the rotor of the second motor, instead of its stator, is supplied from the first motor.

CASCADE PARALLEL CONTROL. — This method differs from the above in that both motors are connected to the line during normal running at full speed. Both motors have the same number of poles.

CASCADE PARALLEL SINGLE CONTROL.— This method differs from cascade parallel control chiefly in that one motor has more poles than the other. Designating the motors as IV and VI, let us take a case where IV has four poles and VI has six poles. At starting IV is thrown on the line and feeds VI in cascade. As soon as cascade synchronism is reached, after having decreased to zero the resistances in the secondary circuit of VI, the secondary of IV is transferred from VI to suitable resistances, resistances are again inserted in the secondary of VI, and VI is then thrown on the line in parallel with IV. The resistances in IV and VI are reduced until VI's resistances are reduced to zero, and its synchronous speed is reached. VI is then cut out of circuit, and the resistances of IV are further decreased until, when they are reduced to zero, IV will attain its synchronous speed. Thus, for running at top normal speed, IV does all the work and VI is idle. See also SYNCHRONISM, CASCADE. (Ref. 'Electrical Traction', vol. ii, pp. 62 – 65, Wilson and Lydall.)

Cascade Starting and Control. See STARTING OF MOTORS.

Cascade Synchronism. See SYNCHRONISM, CASCADE.

Casing (or Moulding) for Interior Wiring. See WIRING SYSTEMS.

Cast-grid Resistances. See RHEOSTATS.

Cast Iron. See IRON.

Cast-iron Conduit. See CONDUIT, UNDERGROUND.

Cast Rail Bond. See BOND; WELDED RAIL JOINT.

Cast Steel. See STEEL.

Cast-welded Rail Joints. See WELDED RAIL JOINT.

Catchnet, a structure erected below h pr overhead transmission lines for protection from the occurrence of damage from such lines. In a Bill introduced in 1908 in the New York State Legislature it is stipulated that a suitably grounded catchnet shall be installed under every line of 20,000 volts or over, where the line crosses public streets, highways, railway tracks, canals, and where it passes over other aerial wires. The net must be at least 2·5 m below the h pr circuit. It must not be less than 6 m wide nor less than 7 m from the ground, nor less than 1·25 m from any other wire. It is further stipulated that the catchnet shall be supported by poles, towers, or other structures erected outside of the limits of the public street or highway, for the full width of the crossing, and at least 2 m beyond on each side, and of sufficient width and so constructed as to assure the retention of any transmission lines that may fall upon it.

Catenary Cable Bearer. See CATENARY SUSPENSION.

Catenary Suspension. — In electric traction on railways for high speeds it is necessary to support the trolley wires at a practically uniform level. This is accomplished by suspending the wire from a *bearer cable,* which hangs between its supports in the form of a catenary curve; the *droppers* which carry the trolley wire are spaced at short intervals, and are of varying lengths to compensate for the curvature of the bearer cable. In some cases two bearer cables are used to support a single trolley wire (*double catenary suspension*). These systems are much used in connection with ac railway traction.

Cathode, the conductor by which current flows away. The term is usually applied to a solid conductor by which current flows out of a liquid or gas, *e.g.* an electrolytic cell or vacuum tube. (Derived from Greek, meaning the 'downward way'.) Also spelled *kathode* and *katode.* See also ELECTROLYSIS.

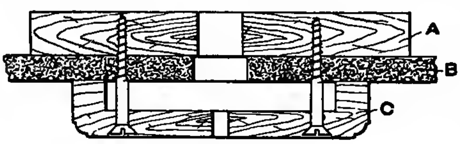
Cathode Ray, a stream of negatively charged molecules repelled from the cathode of a vacuum tube. The oscillations of these molecular charges, when they strike the walls of the tube, create short, damped trains of free electrical waves of very hf (greater than that of visible light) to which only good conductors are opaque. These waves are the Röntgen rays. Opacity is caused by absorption of energy through revibration (resonance) of the molecules of the opaque substance, and as such irregularly occurring damped trains of waves cannot in general cause revibration, they are but slightly absorbed and pass through considerable thicknesses of most materials (see RÖNTGEN RAYS). The cathode ray, being an electric current, is deflected by a magnetic or electric field, and, having practically no inertia, forms a suitable indicator for rapidly varying magnetic or electric forces (see 'Braun's Cathode-ray Oscillograph' under OSCILLOGRAPH). The impact of the molecules may give rise to visible as well as invisible radiations (*fluorescence*). [J. E-M.]

Cathode - ray Oscillograph. See OSCILLOGRAPH.

Cathodogram, a record taken with a Braun's cathode-ray oscillograph (which see).

Cc, the preferable abbreviation for continuous current (which see).

Ceiling Block, a block of wood, or preferably of fireproof material, which is used



Ceiling Block

A, Wood block; B, ceiling; C, ceiling block.

as a foundation for securing ceiling-roses (which see) or other fittings to the ceiling. It is fixed in place by screwing it to another block of wood, or of some fireproof material, placed above the ceiling as shown in the figure. In other cases the ceiling block may be secured by screws directly to the laths of the ceiling.

Ceiling-rose.—When electric lamps are suspended from above by means of flexible wires which also serve to convey the current to them, the connection between the flexible wires and the source of supply is usually made through what is termed a *ceiling-rose.*

The ceiling-rose consists essentially of a china or porcelain block secured to the ceiling by screws, and bearing two insulated brass terminals, connected to the source of electricity. To these the two ends of the flexible mains are attached, and then threaded through an aperture in the cover of the block. In the best ceiling-roses the china part of the base is so arranged that the brass fittings have a china partition between them, to prevent them from being short-circuited. These partitions have holes in them through which the flexible wires are threaded, and they are thus able to carry the weight of the pendant.

Cell.—

['*Cell,* (*a*) a source of electrical energy dependent on chemical action, complete in itself; (*b*) a compartment of a h pr cellular switchboard; (*c*) a combustion chamber of a dust or refuse destructor.'—I.E.C.]

Cell, Accumulator, Element of, a positive and negative group of plates with separators.

Cell, Battery. See ACCUMULATOR.

Cell, Bichromate. See BATTERY, PRIMARY.

Cell, Bunsen. See BATTERY, PRIMARY.

Cell, Cadmium Standard. See CELL, STANDARD.

Cell, Chloride of Silver. See BATTERY, PRIMARY.

Cell, Closed Circuit. See BATTERY, PRIMARY.

Cell, Counter emf, a cell containing plates from which no capacity is required, and which are inserted in opposition to the main battery pressure to reduce it. They sometimes replace regulating cells.

Cell, Daniell, a primary battery in which the positive electrode is of copper and the negative of zinc. The cell is of the two-fluid type, the exciting solution being zinc sulphate surrounding the zinc electrode in a cylindrical porous pot. The depolarising solution is copper sulphate. The copper electrode often forms the container, and becomes thicker as the cell is worked, owing to the deposition of copper from the copper sulphate. A shelf is provided by which some crystals of copper sulphate are held near the surface of the liquid, to replenish the solution as it becomes spent. The Daniell is one of the most constant in emf and resistance, and is largely used for telegraph work on this account. Its emf is 1·07.

Cell, Dry. See BATTERY, PRIMARY.

Cell, Edison Lalande. See BATTERY, PRIMARY.

Cell, End, of an Accumulator. See ACCUMULATOR, END CELLS OF.

Cell, Grove. See BATTERY, PRIMARY.

Cell, Open-circuit. See BATTERY, PRIMARY.

Cell, Pilot. See PILOT CELL OF ACCUMULATOR.

Cell, Portable, one or more cells with the acid sealed in so as to be easily carried about. If there are several cells in series, *e.g.* five, it would be called a 10-volt portable cell.

Cell, Primary. See Battery, Primary.

Cell, Regenerative, a term which, as usually employed, is synonymous with secondary battery or accumulator (see Accumulator); but the term is occasionally applied to a primary battery which, if allowed to rest, has good recuperative powers.

Cell, Secondary. See Accumulator.

Cell, Short Circuit in a, contact between plates of opposite polarity.

Cell, Standard.—For a laboratory standard of potential a carefully constructed primary cell is used. The emf of certain cells will remain constant for an indefinite period if they are only used as standards of emf. Great care is required in the construction, and only minute currents should be taken from the cell, in order to avoid as far as possible any error due to polarisation or to exhaustion of the exciting fluid. The best-known types are:

The Clark Cell.—To make it possible to obtain a standard of emf without reference to the Government standards, the Board of Trade issue a minute specification for the construction of a cell of the Clark type. This will give an emf of 1·434 volts at 15° C. The temperature correction is applied by using the formula:

$$E_t = E_{15}\left[1 + a\,(15 - t)\right],$$

where E_t = emf required at a temperature t.

E_{15} = 1·434 volts in this case,
a = temp. coeff. = 0·0008.

The cell may take the ordinary test-tube form or the **H** form as in the Weston Standard; the materials are rendered as pure as possible chemically. In the test-tube form the negative is a stick of pure zinc, and in the **H** form it consists of an amalgam of zinc and mercury. The positive pole in both types is pure mercury, and the exciting and depolarising mass is a paste of mercurous sulphate and a saturated solution of zinc sulphate. The mercury being at the bottom of the tube, connection is made to it in the tube form by means of a platinum wire (No. 22 gauge) inside a small glass tube, which effectually prevents contact with the paste. The platinum wire projects out of the glass tube under the surface of the mercury, the glass being fused round the wire at the bottom end. In the **H** type the connection is made to both electrodes by platinum wires fused through the glass forming the lower limbs of the **H**.

The Hibbert Cell.—This cell is similar to the Clark, except that the chlorides of the metals are substituted for the sulphates. The emf is 1 volt, and at ordinary temperatures the emf is nearly independent of temperature variations.

The Weston Cadmium Cell.—This is usually of the **H** form, the electrodes being mercury for the positive and an amalgam of cadmium and mercury for the negative. The bottom ends of the limbs of the **H** are sealed in with a platinum wire passing through the glass of each. The electrodes are placed at a sufficient depth to cover the wires, and the exciting fluid is filled in to above the level of the cross connecting tube. The exciting fluid is a neutral concentrated solution of cadmium sulphate. The top ends of the limbs are corked and sealed in with paraffin wax. In making the cadmium amalgam, from 6 to 13 parts of mercury may be mixed with 1 part of cadmium without appreciably affecting the emf. Great care must be taken to use the purest materials. [F. C.]

Cell, Stationary, a cell designed and arranged on the understanding that it will not be moved from place to place. Stationary cells are usually of much heavier construction than traction cells (see Accumulator), since there is no occasion to sacrifice durability to weight.

Cell, Storage. See Accumulator.

Cell, Traction. See Accumulator.

Cell, Voltaic.—A voltaic cell consists of two dissimilar electrodes in a solution or electrolyte which has a chemical action on one of the electrodes. The general type is exemplified by the simple cell, consisting of zinc and copper in dilute sulphuric acid. Such a combination is also known as a couple, a galvanic or voltaic couple, and sometimes as a galvanic or voltaic battery. The electrode which is acted upon is the negative electrode. Hydrogen is usually produced in this chemical reaction and is liberated at the other pole (in the simple couple, at the copper pole). This causes polarisation (which see), and some substance is usually added to the combination for the purpose of preventing polarisation.

This substance is called the depolariser (see DEPOLARISE).

SINGLE-FLUID VOLTAIC CELL, a cell in which the depolariser forms part either of the positive or of the fluid. An example of the former is the Edison Lalande cell, and of the latter, the bichromate cell. These two cells are described under BATTERY, PRIMARY. The term single-fluid serves to distinguish such cells from two-fluid cells (*e.g.* the Grove or Bunsen), where the depolarising fluid is separated from the exciting fluid by means of porous cups or pots. The Grove and Bunsen cells are also described under BATTERY, PRIMARY.

Cell Inspection Lamp for Accumulator. See LAMP, CELL INSPECTION, FOR ACCUMULATOR.

Cells, Grouping of. — The individual cells of an accumulator should never be connected in parallel (multiple), and the practice of coupling two or more groups of the same number of cells in parallel in order to increase the available capacity, or to enable a higher discharge rate to be obtained, is permissible only when suitable means are taken to ensure equal work for each group of cells. This is even more essential when the capacities of the various groups differ, or when one group consists of new cells and the other or others of old ones.

It is preferable to have one large battery (*i.e.* accumulator) of the desired capacity rather than to arrange two or more sets in parallel to obtain the same output.

Cells, Milking. See MILKING CELLS OF ACCUMULATOR.

Cells, Regulating, cells of an accumulator which are fitted with separate conductors to the switchboard, and are used for regulating the pressure of the accumulator.

Cell Tester. See VOLTMETER.

Cell Tester for Accumulator. See TESTER, CELL, FOR ACCUMULATOR.

Cellular High-pressure Switchboard. See SWITCHBOARD, CUBICLE OR CELLULAR TYPE OF HIGH-PRESSURE.

Cement-lined Conduit. See CONDUITS, UNDERGROUND.

Centi-ampere, a unit used in the measurement of small currents, being $\frac{1}{100}$ amp. It is principally used in connection with certain measuring instruments due to Lord Kelvin and known as *centi-ampere balances.* See AMPERE and KELVIN BALANCE.

Centi-ampere Balance. See AMPERE BALANCE.

Centimeter-gram-second System.— See UNITS, CENTIMETER-GRAM-SECOND SYSTEM OF.

Central-battery System, a method of telephone working in which the energy is supplied by a battery in the exchange, instead of by the older method of a battery at each subscriber's instrument.

Central-battery Working, a system of working subscribers' lines by means of a battery in the exchange. See CENTRAL-BATTERY SYSTEM.

Central Station for the Generation of Electricity.—A central station for the generation of electricity may be described as a factory in which the energy liberated by the consumption of fuel or by falling water is converted into electricity. Such a station is often termed an *electricity works.* In most large stations, the only fuel used is coal, this being either burnt under steam boilers for the purpose of driving steam engines, or consumed in the manufacture of gas which is used to drive gas engines. Diesel engines, employing oil as fuel, are now coming into wider use, and while their first cost is high, they are exceedingly economical of fuel.

Where water power is available, the water is used to drive some form of turbine or water wheel (see MINING EQUIPMENT, ELECTRICAL).

DESTRUCTOR STATIONS.—*Refuse as Fuel.* —In some steam stations the coal is supplemented, and during periods of light load superseded, by fuel consisting of the refuse of the district, such as pressed sewage, sludge, the contents of dustbins, &c., special furnaces being provided for its consumption. An interesting example of a destructor station is that at Shoreditch, which is very fully described in a paper by Russell (Proc. I.C.E., vol. cxxxix, p. 181).

Bye-products from Destructor.—The clinker and ash resulting from the burning of the refuse constitute a bye-product which, combined with Portland cement, is made into concrete paving slabs, or other product.

The economy resulting from the burning of refuse in electricity supply stations is usually found not to be sufficient to warrant the erection of stations on this system, except in cases where no other means of destroying the refuse are conveniently available.

The following is a general description of a steam station of the present standard design. It is the central station at Derby, and is fairly typical of a moderate-sized elec-

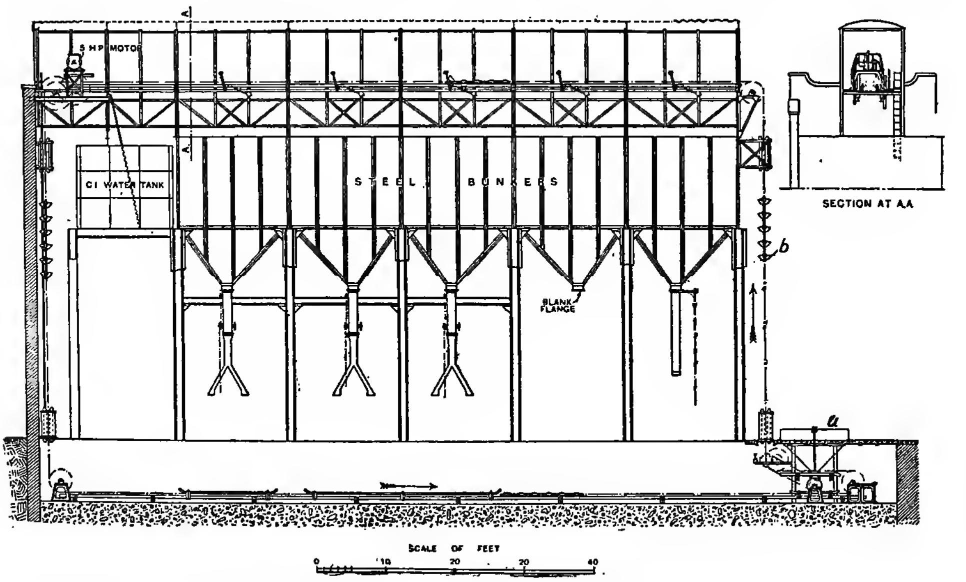


Fig. 1.—Arrangement of Coal Bunkers at Electricity Works at Derby

tricity works employing steam turbines. It is fully described in 'Electrical Engineering' for Dec. 19, 1907, from which figs. 1 and 2 are reproduced by permission. The coal

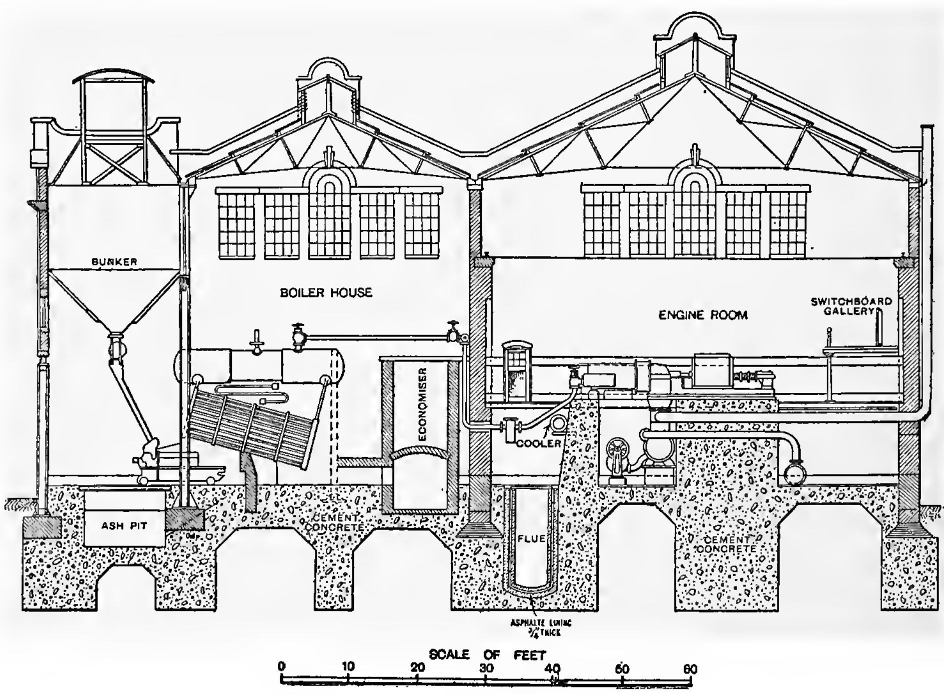


Fig. 2.—Section of Electricity Works at Derby

brought to the station is tipped into a hopper *a* (see fig. 1), from which it is fed into the buckets *b* of the *conveyor*. This *conveyor* consists of pivoted brackets carried by an endless chain which moves continuously in the direction shown by the arrows.

It is driven by a small 5-hp motor. As the buckets arrive at a required point over the steel *bunkers*, they are caught by a trigger, which causes them to tip their contents. They then proceed empty until they again arrive at the hopper, where they receive a fresh load of coal.

From the bottom of the bunkers, pipes are led to the boiler furnaces, the flow of coal to the grates being regulated by valves in the pipes. The coal is fed to the front of the grate, and is caused by mechanical means to travel gradually through the furnace, being consumed as it goes along. The residual ash falls over the end of the grate, and is guided by an inclined passage to the ashpit. Here another conveyor, similar to that used for the coal, is employed to transfer the ash to a convenient spot. Thus the progress of the coal through the station is effected entirely by mechanical means, and the cost of handling is reduced to a minimum.

Coal Consumption.—The cost of coal is one of the most important items in the cost of producing electricity. This cost may be kept to a minimum by attention to three principal points. (1) By installing machinery of high efficiency, and maintaining this efficiency in regular work, the quantity of coal required is reduced to a minimum. (2) By making calorimeter tests of coal samples and ascertaining which will give the largest amount of heat energy for the price paid for it, the outlay for coal is brought to its lowest figure. (3) The cost of handling in the station itself requires to be closely watched. The most convenient figure of comparison of the cost of coal in different stations is the cost of the coal required per kelvin, or kw hr (which see) of electricity sold. The following values of this figure for different stations are taken from the 'Electrical Times': Shoreditch, 0·5*d.* per kw hr; Aberdeen, 0·27*d.*; Manchester, 0·21*d.*; Kendal (very small station), 1·41*d.*; Newcastle-on-Tyne, 0·13*d.*

Water Consumption.—After coal, the next most important material required in the process of manufacturing electricity, is water. This is required mainly for two purposes: firstly, to be converted into steam to drive the engines; and secondly, to condense the exhaust steam. In stations using steam-turbines, a quantity of water, comparatively insignificant to that required for the other purposes, is used for cooling the oil used to lubricate the turbine and generator shafts. The water is usually drawn from a river, and requires first to be strained or filtered to remove suspended matter. If the water contains carbonates of lime and magnesia, &c., it requires also to be treated with lime to precipitate these carbonates, since, if not removed, they form scale in the boilers and so reduce the efficiency of the plant. The water is then passed through an economiser, in which it receives heat from the waste furnace-gases on their way to the chimney, or through a feed-water heater in which it receives heat from the exhaust steam from the engines. Finally it enters the boilers at a temperature of some 180° F. (82° C.)

The steam is led from the boilers to the engines by a system of steam pipes, and after doing its work in the engines, the exhaust steam is led to a condenser by a second system of pipes. After condensation, the water is passed back to the boilers by way of the economiser (or feed-water heater as the case may be), and the cycle of operations is repeated continuously. During these operations a certain loss of water occurs, and this is made up by fresh water which has been passed through the softener and filter.

Heat Insulation.—In order to prevent or reduce the loss of energy by the radiation of heat from the surfaces of the boilers, steam pipes, and engine cylinders, these surfaces are covered with some form of heat insulator, the materials chiefly used for this purpose being asbestos, slag wool, or fossil meal, held in a covering of canvas or sheet steel.

Steam Consumption.—As the amount of coal burned in the boiler furnaces is proportional to the amount of water evaporated, the quantity of steam required by the engines is an important figure. This quantity is generally expressed as the lb (or kg) weight of steam supplied to the engine cylinder per kw hr (*i.e.* per kelvin) of electricity generated, or preferably the lb (or kg) weight of feed water supplied to the boilers for the same quantity of electrical energy. A representative figure is 30 to 35 lb (13 to 16 kg) of water per unit generated; but of course the figure varies greatly with the type and size of plant, and far lower figures are obtained in large modern electricity works equipped with large steam turbines or piston engines. The steam engines which drive the dynamos may be of either of these types: (1) large slow-moving engines running at speeds of 90 to 180 rpm, (2) smaller engines running at quick speeds of 300 to 600 rpm, or (3) steam turbines running at 500 to 3000 rpm.

WATER POWER.—Where water power is to be used, a reservoir is formed at an elevation by building a dam across a river or stream. From this reservoir the water is led down in pipes to the power house, where it drives turbines or Pelton waterwheels (see MINING EQUIPMENT, ELECTRICAL).

GAS POWER.—In cases where the power is generated by the explosive combustion of gas, coal gas is only used to a limited extent, water gas being employed in the great majority of cases. Several makes of apparatus are on the market for the production of this gas. The general principle of the producers is the same in all cases. The formation of the gas is effected by passing steam over or through incandescent coke, and the gas is then led from the producer to the engine. Large central stations working with gas power have not, so far, been an unqualified success, but in smaller plants very satisfactory results have been achieved.

Whether steam, water, or gas power be used, the general principle of the dynamos is the same, their speed generally being the same as that of the prime mover, as direct coupling is now practically universal. Belt or rope driving for large powers is no longer employed.

MAIN SWITCHBOARD.—From the dynamos copper cables conduct the current to the main switchboard. On this board the current from each dynamo is led through suitable switches and safety appliances to the main copper bars known as bus-bars. Connected to these bars are the switches which admit the current to the various external distribution circuits. On the main switchboard are also mounted the necessary instruments for measuring the quantity of electricity generated and distributed.

LIGHTING AND POWER. — The current generated in and distributed from a central station is chiefly used for purposes of lighting and power, separate mains being preferably laid for the two purposes. In the case of large stations supplying an extended area, the electricity generated is usually alternating and three-phase and of high pressure.

SUBSTATIONS.—The electricity is led by suitable cables to substations or transforming stations, where it is transformed down to a lower pressure or converted into cc. by means of transforming machinery.

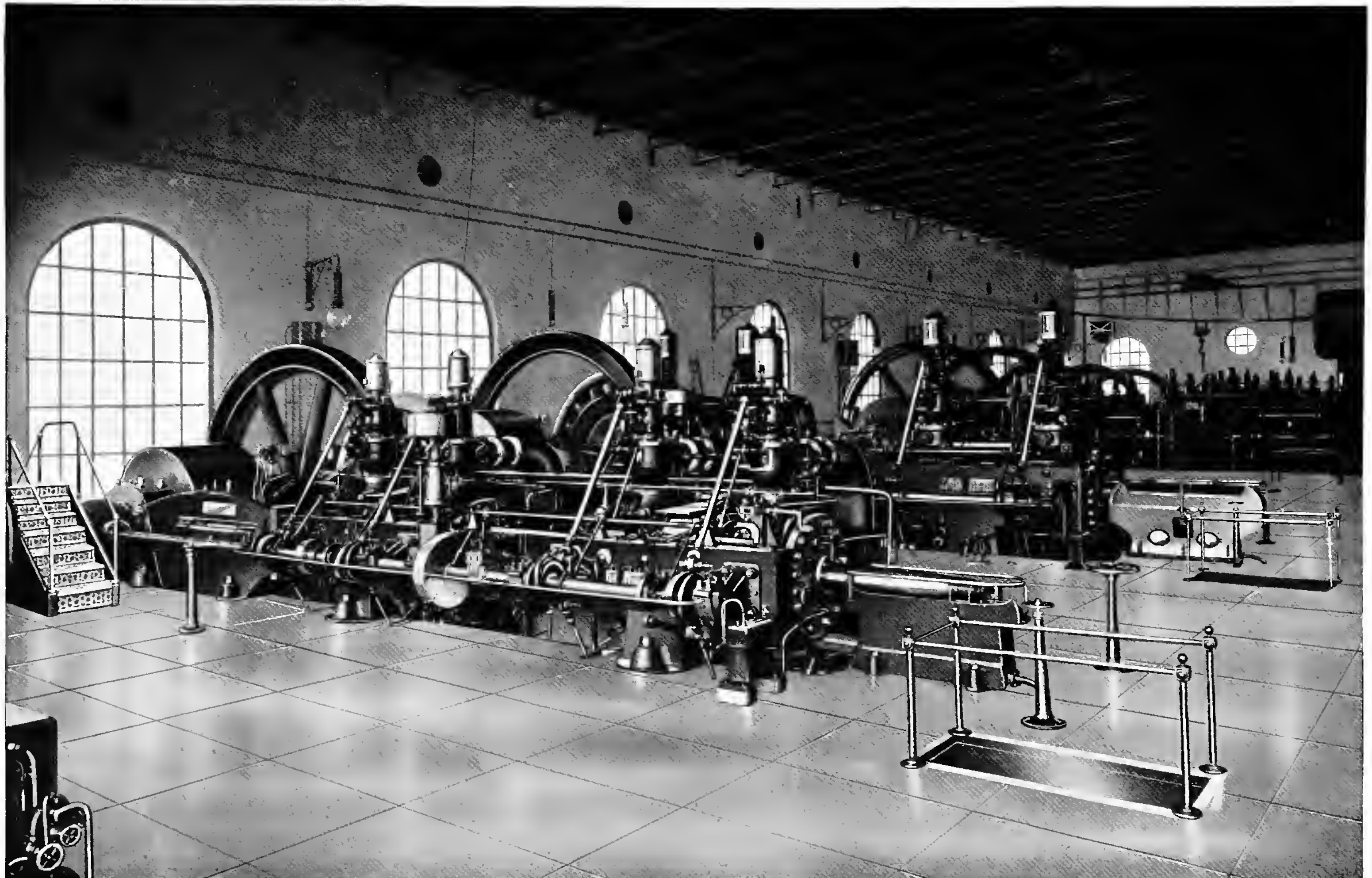
TRANSFORMING MACHINERY.—This may be of either of two types. The *static transformer* is exclusively for ac, and consists, in principle, of two coils wound on a laminated iron core, which forms a complete magnetic circuit. To one of these coils —the primary—the current from the central station is led, and this current, circulating in the coil, sets up an alternating magnetic flux in the iron circuit, which induces other currents in the second (or secondary) coil. This form of transformer does not alter the character of the current, which still remains ac and of the same periodicity as the primary current, but it alters the pressure, reducing or increasing it, according to the number of turns on the respective coils. Thus, if the number of turns on the primary coil is ten times that on the secondary, the pressure supplied at the terminals of the latter will be one-tenth of the pressure applied to the terminals of the primary.

A *motor-generator* may be used to alter the character of the current supplied to it as well as to transform the pressure. Its principal use is to convert ac of high pressure to cc of moderate pressure for traction and power purposes.

The motor-generator may consist of two separate machines coupled together. One, acting as a motor, is supplied with current from the central station, and the other, acting as a dynamo, supplies the class of current and pressure required at the substation; or it may consist of one machine, the armature of which carries slip rings at one end and a commutator at the other, the connections of these to the armature winding being such as to give the required conversion. When the motor-generator thus consists of one machine, and when it receives alternating electricity and delivers continuous electricity, it is termed a *rotary converter*. (Ref. 'Electric Machine Design', pp. 309 to 394, Parshall and Hobart.)

FLUCTUATING DEMAND.—The demand for current from a central supply station is of a fluctuating character. The demand varies with the time of year, and also varies from hour to hour during each day.

LOAD CURVE.—The demand may be represented graphically by means of a curve generally known as a load curve or load diagram.



ELECTRICITY SUPPLY STATION DRIVEN BY BLAST FURNACE GAS AT THE BARROW HEMATITE STEEL WORKS

[*To face p. 92.*

In figs. 3 and 4 two load curves are given. The first shows the load on the bus station of the Charing Cross and City Electric Supply Company during 1904, and is taken from a paper by Patchell at p. 66 of vol. xxxvi of the Journ. of the I.E.E. The second shows the load on the Shoreditch station during one day, and is taken from Russell's paper already mentioned. The shape of the curve from any given station will vary with the nature of the load.

LIGHTING LOAD.—If the demand is chiefly for electricity for lighting, the load will be small during the greater part of the day and very large from about 4 to 9 p.m. or later, according to the time of year.

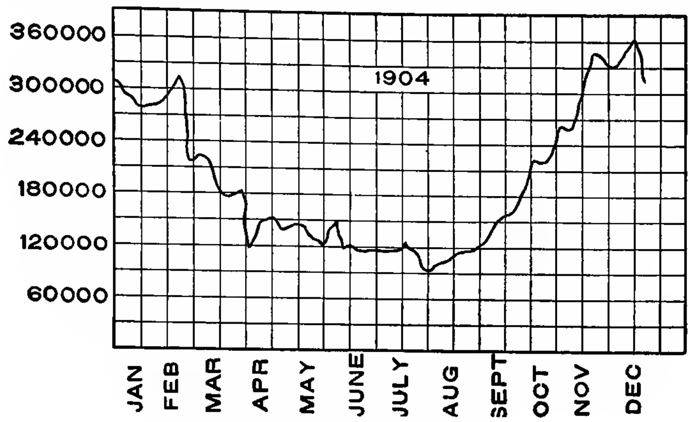


Fig. 3.—Load Curve for One Year

POWER LOAD.—Where electricity is supplied for power purposes to a number of factories, the load is fairly steady during the ordinary working hours of the factories, dropping, of course, during meal times.

TRACTION LOAD.—The load on a station supplying electricity for traction purposes is fairly steady as to its average value, but there are violent fluctuations from minute to minute, due to the large currents required for the starting and acceleration of the cars or trains.

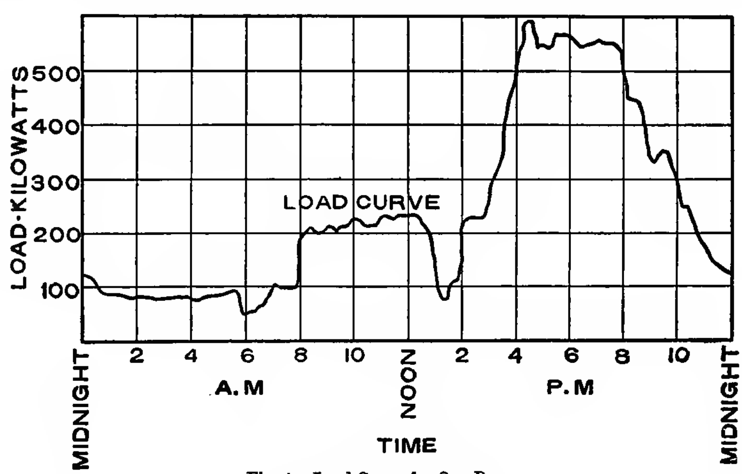


Fig. 4.—Load Curve for One Day

PEAK.—On the load curves drawn in figs. 3 and 4 it will be noted that the load at one point rises to a very high value. This load is sometimes described as the *maximum demand*, but is more generally known as the *peak* or *peak load*. The term maximum demand has also been used to denote the load that there would be if all the customers required to be supplied with their individual maximum demands simultaneously. This, of course, never happens, as the periods of maximum demand of private houses, factories, shops, &c., are all different. The former definition of maximum demand is the one in wide and accepted use.

Load Factor.—The machinery of the station must obviously be at least sufficient to supply the peak load, and must therefore be considerably in excess of that required for the *average* demand. The figure showing the relation of the average to the maximum load is known as the load factor, and was originally suggested by Crompton. It is obtained as a percentage by multiplying the number of units sold (per annum) by 100, and dividing by the product of the maximum load and the number of hours in the year. This gives the *annual station-load factor*. It is valuable to know, in addition, the *diurnal-load factor*, which is arrived at in the same way, but taking the figures for 24 hr instead of a year.

It is also, in some cases, of interest and value to ascertain the load factors of separate districts served from the same station, as these may vary considerably.

Station-load Curves.—The curves given herewith, and already mentioned, are station-load curves, that is to say, they show the whole output from the station at any time. Detail load curves applying to each district yield further useful and suggestive information.

Diversity Factor.—Another valuable figure is the diversity factor, which is the ratio of the actual maximum load on the feeders, to the sum of the maximum demands of all consumers

$$= \frac{\text{max. load on feeders in kw}}{\text{sum of consumers' max. demands in kw}}.$$

['*Diversity factor*, the number obtained by dividing the actual output of any works during a given period of time by what that output would have been had the works operated throughout the whole of that period at the maximum load reached during that period.'—I.E.C.]

Standby Charges.—As the amount of machinery required in a central station is greatly in excess of that required to supply the average demand, and as this machinery must always be kept in a state of preparation to supply the maximum demand whenever it may arise, it was suggested by Dr. John Hopkinson that the cost of running a station should be divided into two items—firstly, the cost of keeping the machinery in a state of preparation, and including charges on capital, which he called the standby charge, and expressed as the cost *per annum per kw installed*; and secondly, the cost of *generating* the electricity, expressed in pence per kw hr of output. The figures were worked out by Mr. Wright for the Brighton Station, and amounted to £18 and 0·71*d.* respectively.

In Messrs. Merz and McLellan's paper on power-station design, curves are given showing the relation between these figures with different load factors and different initial capital cost. Since the greater the discrepancy between maximum and mean demand the greater are the standing charges, it is very desirable to obtain a high load factor. The direction in which this may be accomplished is by stimulating the demand for energy during those periods in the 24 hr in which it is not required for lighting, so as to equalise as far as possible the load on the station.

Spare Plant.—In addition to the machinery required to supply the peak load, it is necessary to install additional machinery to take the duty of any which may happen to break down, and such machinery is generally referred to as spare plant. Owing to the increasing reliability of electrical plant, and the increasing employment of accumulators, the quantity of spare plant considered necessary is steadily decreasing. In many cases accumulators are taking the place of spare plant with quite satisfactory results. Some engineers, however, take the view, in support of which they have a strong case, that additional steam plant leads to greater total economy than is attainable by employing accumulators in steam stations.

Efficiency.—If we take efficiency as meaning the ratio of the energy supplied from the station to the energy contained in the coal burnt in the boiler furnaces, the overall efficiency of a central generating station is extremely low, rarely being much more than 5 per cent. That is to say, of every 100 tons burnt in the boiler furnaces nearly 95 tons are usually wasted; so that there is still much room for improvement. The greatest loss takes place in the engines, which rarely yield in mechanical work more than 15 per cent of the heat energy supplied to them. A useful comparative figure of efficiency is the cost per unit, *i.e.* per kw hr or per kelvin, delivered from the Electricity Works. A comparison of the details of this figure for a number of stations, provides a useful means of ascertaining where economies may be effected. See also EFFICIENCY.

CAPITAL COST.—The capital cost of an electrical plant should properly include all expenditure on machines, erection, and so on, up to the time at which the machinery is set into regular use for the supply of electric energy. Extensions of the machinery for the purpose of increased supply would also be charged to capital account.

MAINTENANCE COST.—Maintenance cost includes all costs incurred in keeping the machinery in good order and in a proper state of repair after it has been started to work.

DEPRECIATION.—In all cases where machinery is used, it is customary to set aside a certain sum each year according to the probable life of the machinery, so that when it is worn out there will be a sufficient sum in hand with which to provide new plant. Thus, if the life of a machine is twenty years, 5 per cent of its cost would be put aside each year.

SINKING FUND.—Where a station is working on capital borrowed for a term of years, a percentage on this capital is set aside each year in order to extinguish the debt, and this is known as the sinking fund. It is of course distinct from, and in addition to, the percentage paid as interest.

(Ref. 'Central Stations', C. H. Wordingham; 'Cost of Electrical Energy', R. E. Crompton, Journ.I.E.E., vol. xxiii, p. 396; 'Cost of Electrical Energy', R. E. Crompton, Proc.I.C.E., vol. cvi, p. 2; 'Power Station Design', Merz and McLellan, Journ.I.E.E., vol. xxxiii, p. 696; 'Niagara Power Station', Prof. Forbes, Journ.I.E.E., vol. xxii, p. 448.)

[C. W. H.]

Central Station Supply. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Central Suspension. See SUSPENSION OF TRACTION MOTOR.

Central Switchboard. See SWITCHBOARD, CENTRAL.

Central Telephone Exchange, an exchange in the centre of a district, through which the outlying exchanges communicate with one another.

Central-zero Ammeters. See AMMETERS.

Centre of Distribution (or distributing centre), the point from which distributing cables or conductors branch out to the various consumers or consuming devices. Feeders (feeding cables or conductors) are run from the source of supply to the *distributing centres*, and, as these feeders are in many cases of considerable length, a substantial loss of pressure generally occurs in them. The pressure at the source of supply, however, is so regulated as to compensate for the drop in the feeders, and the pressure at the distributing centres is thus kept constant; or the same result is obtained by the use of regulating devices in the feeders. The essential condition in most systems is that the pressure at the distributing centres shall be kept practically constant, irrespective of the load. (Ref. 'Central Electrical Stations', C. H. Wordingham.)

Centre-pole Suspension. See TROLLEY-WIRE SUSPENSION.

Centre Slot. See CONDUIT SYSTEM OF ELECTRIC TRACTION.

Ceresine, sometimes termed *Cerasin*, the mineral resin ozokerite bleached to remove the colouring matter. After bleaching, it has a light-yellowish colour, and is sometimes used in the manufacture of insulating compounds. See also OZOKERITE.

Cgs, the preferable abbreviation for Centimeter-gram-second. See UNITS, CENTIMETER-GRAM-SECOND.

Chain Coal-cutter. See ELECTRIC COAL-CUTTER.

Chain Winding. See WINDING, CHAIN.

Chamfer of Pole Shoes. See 'Bevelled Pole Shoe' under POLE SHOE.

Change-over Clock. See SWITCH, TIME.

Channel Bar, a lead bar to which the plates of adjacent cells in a battery of accumulators are burnt.

Characteristic Curves. See CURVE, CHARACTERISTIC.

Charge, Density of, the amount of electricity per unit area. This is proportional to the number of lines of electric force terminating on unit area if the surface is a conductor.

Charge, Dissipation of.—The charge on an insulated electrified body may generally be dissipated by exposure of the body to ultra-violet rays. The rate of discharge differs for different surfaces, and is usually greater for negative than for positive electricity.

Charge, Distribution of.—On an insulated conductor, in electrical equilibrium, the charge distributes itself so that the lines of force become approximately radial straight lines from a centre, and the equipotential surfaces become approximately spheres. The distribution of charge is thus dense on convex parts of the conductor and less dense on concave portions. On an infinitely fine point the density would be infinite, and in a completely enclosed hollow it would be zero. These laws hold only in cases of static equilibrium.

Charge, Residual.—A condenser with a solid dielectric is not completely discharged by the first discharge, but will give another though smaller spark after an interval of a few seconds. This is called a *residual charge;* it is supposed to "soak out" of the dielectric when the stress is removed.

Charge, Static. See STATIC CHARGE.

Charge and Discharge Cycle.—The chemical occurrences at the negative and positive plates during discharge and charge may, in a lead cell, be considered to be as follows:—

Discharge:

$$Pb + H_2SO_4 = PbSO_4 + H_2.$$
(Negative plate)

$$PbO_2 + H_2 + H_2SO_4 = PbSO_4 + 2H_2O.$$
(Positive plate)

Charge:

$$PbSO_4 + H_2 = Pb + H_2SO_4.$$
(Negative plate)

$$PbSO_4 + O + H_2O = PbO_2 + H_2SO_4.$$
(Positive plate)

This constitutes a cycle of charge and discharge.

Charge and Discharge Key. See KEY, CHARGE AND DISCHARGE.

Charging at Constant Potential. See CHARGING CURRENT.

Charging Booster. See BOOSTER.

Charging Current.—The usual method of charging a battery of accumulators is to maintain the current at a constant value throughout the operation, decreasing it slightly when the cells begin to gas. Occasions, however, sometimes arise when the cells have to be recharged from a constant potential circuit, when the rate of charge will vary according to the relative potential difference of the battery and the charging circuit.

Charging Gear, Cable. See CABLE CHARGING GEAR.

Charring of Insulator Pin. See INSULATOR PIN.

Chattering of Brushes. See BRUSHES, CHATTERING OF.

Chatterton's Compound, a black adhesive material, invented to effect the adhesion of gutta percha to copper in the manufacture of submarine cables; is also considerably used for various adhesive purposes, being moisture-proof, and not so brittle as sealing-wax. It will not adhere to a damp, oily, or cold surface. It must not be heated to too high a temperature, as its adhesive properties will thereby be destroyed.

Cheek-type Frame. See FRAME, STATOR.

Chemical Electric Meter. See METER, ELECTROLYTIC.

Chemical Energy. See ENERGY.

Chemical Meter. See METER, ELECTROLYTIC.

Chemical Rays. See LIGHT, ULTRA-VIOLET.

Chicago Crown and Rail Bonds. See BOND.

Chinese Wood Oil, sometimes termed *tung oil.* This is the oil obtained from the seeds of the tung tree, *Elæococca vernica,* by cold pressure, and is the only drying oil, other than linseed oil, that has been employed in the manufacture of insulating varnishes.

It dries quicker than raw linseed oil, but heating does not accelerate its drying power. When heated to a temperature of about 200° C., it sets almost immediately into a clear, transparent jelly, which cannot be melted by any subsequent heating, and is quite insoluble in any of the ordinary solvents. The same result can be obtained by heating at a lower temperature for a considerable time, or by prolonged exposure to light. The chemical composition of Chinese wood oil has yet to be fully determined. See also 'VARSULAT' INSULATING VARNISHES. [H. D. S.]

Chloride Accumulator. See ACCUMULATOR.

Chloride of Silver Battery. See BATTERY, PRIMARY.

Choking Coil. See COIL, CHOKING.

Choking Effect denotes the pressure drop or the current reduction produced in a circuit by the introduction of a choking or reactance coil. See COIL, CHOKING; COIL, REACTANCE.

Chord Winding. See WINDING, CHORD; WINDING, FRACTIONAL PITCH.

Chrome Bronze, an alloy of copper, tin, and chromium. The properties, especially the specific resistance, vary greatly with the varying proportions of the three constituents. Certain measurements have given the following results:—

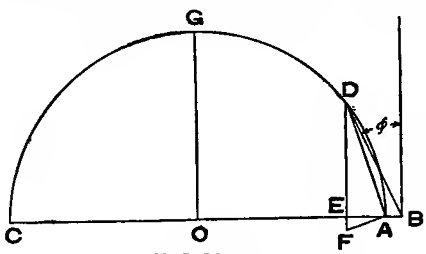
Specific Resistance in Microhms per cu cm. at 0° C.	Ultimate Tensile Strength in kg per sq cm at 0° C.	Specific Gravity.
1·64	4,500	8·9
4·71	7,550	8·9
7·80	10,600	8·9

Chrome Steel. See STEEL.

Churcher Valve. See RECTIFIER.

Circle Coefficient. See BEHREND'S FORMULA; DISPERSION, MAGNETIC; CIRCLE DIAGRAM.

Circle Diagram, a diagram by means of which many of the properties of induction



Circle Diagram

motors and of several other types of ac motors can be graphically investigated.

In the case of the induction motor, for instance, let A B in the figure represent the no-load current flowing in the primary winding when there is no load on the motor; let σ be the circle coefficient. (See DISPERSION, MAGNETIC.) Produce B A to C and make $AC = \frac{AB}{\sigma}$. On A C describe the semicircle A D G C. Then, if the losses in the primary circuit and in the iron core are neglected, and if B D represent the primary current for any one condition of load, the point D will always be on the semicircle A D G C, whatever the load. The perpendicular D E is proportional to the corresponding torque; B F is proportional to the slip, and the pf is equal to cos ϕ. D A is proportional to the current in the secondary winding. If O be the centre of the circle, O G is proportional to the greatest torque which the motor can give; if a greater torque than this be put on the motor, it slows up and comes to rest. If B D be the full-load current, D E will represent full-load torque; and the greatest torque of which the motor is capable will be $\frac{OG}{DE}$ times full-load torque. This is called the *breakdown torque*, and the ratio $\frac{OG}{DE}$ is the *breakdown factor*.

Circle diagrams can be constructed for several types of sp commutator motors. [W. B. H.]

Circuit.—

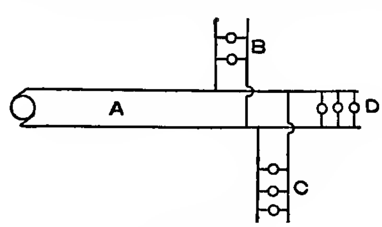
['*Circuit.*—The conductors connected with a source of electrical supply are collectively called a *circuit.* When they form a closed path through which a current circulates, there is a *closed circuit*; when the path is not closed, and no current circulates, there is an *open circuit.*'—I.E.C.]

['*Circuit* means an electrical circuit forming a system or branch of a system.'—Definition accompanying Home Office 1908 Regulations for Electricity in Factories and Workshops.]

See also CIRCUIT, ELECTRIC.

Circuit, Astatic, a circuit, whether magnetic or electric, of such form and dimensions that it is uninfluenced by an external uniform field. Two small, straight, equal magnets fixed parallel to one another on a rigid non-magnetic rod or wire, and having their unlike poles on the same sides, form a simple astatic system. An anchor ring, or tore, uniformly magnetised, is another example. A current circuit in the form of a figure 8 is astatic. In most cases the circuit may be divided into two parts on which the action of the external field is equal and opposite, the stresses caused being balanced by the mechanical elastic forces of the circuit. [J. E-M.]

Circuit, Branch, a circuit which joins one or more other circuits before reaching



Branch Circuits

the generating source. In the figure, the circuits B, C and D are branch circuits, and A is the main circuit, though sometimes D is also, somewhat loosely, termed the main circuit, as the largest amount of power is transmitted by it. See also SUB-CIRCUIT.

['*Branch Circuit*, a circuit which derives its supply of current from points on another circuit.'—I.E.C.]

Circuit, Constant-potential, a circuit with constant terminal pressure (or voltage). See also CONSTANT TERMINAL PRESSURE.

Circuit, Derived. See DERIVED CIRCUIT.

Circuit, Earthed, an electrical circuit which is connected to earth at one or more points. The object of earthing the circuit is to prevent the possibility of any part of the circuit reaching more than a certain pd from earth. A three-wire circuit is frequently earthed at the neutral, in which case the maximum pd of any point from earth can only be that of one side of the system (see THREE-WIRE DISTRIBUTING SYSTEM and EARTHING). A three-phase system is sometimes earthed at a neutral point obtained at the centre of the star windings of the generators or transformers, in which case the mean potential of any point to earth cannot exceed $\frac{1}{\sqrt{3}}$ of the pd between any two conductors, and the insulations and insulators need only be designed to meet this pressure. This is an important consideration where h pr are concerned. Uninsulated return circuits of tramways must also be efficiently connected to earth. In the regulations prescribed by the Board of Trade under the Tramways Act, it is laid down that an uninsulated return, *e.g.* the rails, must be connected to the negative terminal of the generator, and that this terminal must also be in direct connection, through a current indicator, with two separate earth plates not less than 20 m apart, and so arranged that an emf of not more than 4 volts will cause a current of not less than 2 amp to flow between the plates. This test must be made at least once a month. The leakage current from the rails through the earth to the plates must not exceed 2 amp per mile of single track, or 5 per cent of the total current output of the generating station, and this must be tested daily; as a matter of fact a recording ammeter is generally employed for the purpose, thus providing a continuous record.

In cases where it is impossible to employ earth plates so as to comply with the above conditions, the negative terminal may be connected at a single point to a water main, if not less than 3 in internal diameter, with the consent of the owner of the pipe and of the party supplying the water. See EARTH PLATE; EARTHING. (Ref. Board of Trade Regulations under Electric Lighting Acts, 1882 and 1888, revised 1906, also under the Tramways Acts; Trans. A.I.E.E., vol. xxvi, part ii (1907), pp. 1585, 1597, 1605, 1611.

Circuit, Electric.—Any system of conductors carrying, or intended to carry, or which may carry an electric current, is known as an *electric circuit*, or, more briefly, *circuit*.

OPEN CIRCUIT.—Such a circuit, when disconnected from the source of supply, or at any point, is known as an *open circuit*, and when connected, it is termed a *closed circuit*.

EXTERNAL CIRCUIT.—That portion of the circuit of a supply system which is outside the generating station is generally spoken of as the *external circuit*.

SERIES CIRCUIT.—A series circuit is one in which the various apparatus are so joined

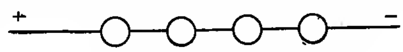


Fig. 1.—Series Circuit

that the same current passes through all. See fig. 1.

PARALLEL CIRCUIT.—A parallel circuit is one in which the lamps, motors, &c., are

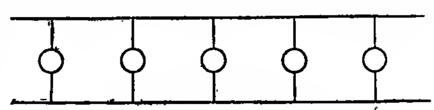


Fig. 2.—Parallel Circuit

connected in independent circuits branching from the mains (see fig. 2). Such circuits are also known as *shunt* or *derived circuits*.

SERIES-PARALLEL CIRCUIT.—A series-parallel circuit is one in which the connections

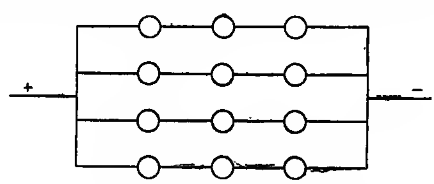


Fig. 3.—Series-parallel Circuit

nections are partly series and partly parallel (see fig. 3). Also sometimes known as a *multiple-series circuit*.

SHORT CIRCUIT.—A short circuit occurs when connection takes place, generally through a fault, between two conductors, whereby the current takes a short cut and is diverted from its proper path. When the short circuit is one of extremely low resistance it is known as a *dead short circuit.*

See also CIRCUIT; CIRCUIT, BRANCH.

Circuit, Exciting. See EXCITATION.

Circuit, Magnetic. See MAGNETIC CIRCUIT.

Circuit, Return, one of the leads between the generating or supply plant and the consuming devices. Either of the leads may be termed the return, but when one is connected to earth, or in certain cases, to other consuming devices, the name *return* is given to that lead; hence the expressions *earthed return* or *common return.* In a cc circuit the negative lead is generally called the *return circuit.* See also FEEDER, NEGATIVE; 'Return Circuit' under ELECTRIC TRACTION.

Circuit, Ringing. See RINGING CIRCUIT.

Circuit, Sonorous, a circuit which has a natural period of oscillation (which see); also a circuit having so low a frequency that its arc makes a musical note.

Circuit Breaker. See also CIRCUIT-OPENING DEVICES; SWITCH.

['A *circuit breaker* is a switch which is opened automatically when the current or the pressure exceeds (or falls below) a certain limit, or which can be *tripped* by hand.'—I.E.C.]

AUTOMATIC CIRCUIT BREAKER, a switch designed to open an electric circuit automatically. There are various kinds of circuit breakers, the design and construction depending upon the object in view, the most common requirements being to break circuit (*a*) at a predetermined excess of current (called a *maximum circuit breaker*); (*b*) at a predetermined minimum current (called a *minimum circuit breaker*); (*c*) at a predetermined reverse current (called a *reverse-current circuit breaker*); (*d*) at both predetermined maximum current and predetermined reverse current (called a *maximum* and *reverse circuit breaker*); (*e*) when the pressure of the system fails (called a *no-voltage circuit breaker*). Of these the maximum, reverse, and maximum and reverse types are the most important.

A maximum circuit breaker is equivalent to a fuse, but has the advantage that it can be at once reset, whereas a fuse has to be replaced. The circuit breaker can also be used as a switch, and in many designs the breaker will open automatically if the load is still excessive, even though the hand be still on the handle. Further, a circuit breaker can be satisfactorily made of much larger capacity than a fuse.

A reverse breaker is used in connection with generators in parallel to cut out a machine automatically if it takes more than, say, 10 per cent motor current. A reverse breaker is also used at the substation end of h pr feeders, where two or more feeders give a supply in order to cut out a damaged feeder as soon as current begins to flow back along it from the other main.

Maximum and reverse circuit breakers are frequently used on generator panels, though many engineers prefer to have reverse breakers only, arguing that if maximum features are incorporated, and one breaker operates, an increased load is thrown on the other machines, with the possibility that their breakers will come into action together, or one after another, and the entire plant be shut down. Feeder circuits are always protected with maximum breakers or fuses.

Circuit breakers are made single, double, or triple pole, and for cc and ac. In practically all cases the automatic feature consists of an electromagnet or of electromagnets energised by the main current or by a shunt current, either directly or through current or pressure transformers, or through relays, which act upon a release or trigger, and so allow the switch contacts to open under the action of gravity or of a spring. In many cc breakers the arc at the final break is blown out by a magnetic field, while in others satisfactory operation is attained by the use of auxiliary contacts of carbon, which can be easily renewed when required.

It is now usual to make ac breakers to operate under oil for pressures above, say, 1000 volts. They are, as a rule, then termed *oil-break switches* (see SWITCH, OIL-BREAK), with maximum, &c., release. In order that no dangerous pressure may be brought on to the mechanism of the release, current and pressure transformers are employed, and where it is desired that the operation of reverse-current releases shall be independent of the pressure of the circuit, they are operated from a separate source, which is frequently cc obtained from primary or secondary batteries. It may be mentioned that a good ac reverse circuit breaker is difficult to design, owing to the varying effect under different values of the pf. Circuit breakers are frequently fitted with *time-limit attachments*, which act as dampers and prevent the too sudden operation of the breakers on what may be only a temporary overload or reverse current. By having different time limits on feeder and generator breakers it can be ensured that the former operate before the latter, and similarly in other cases where it is desired that one breaker shall operate before another. These time limits generally consist of a clockwork device, or of a weight acting on a small drum or pulley, of a modified dash-pot arrangement, or of a device operating by the expansion of a conductor due to the heat generated by a current passing through it. A time-limit device should be so arranged that the heavier the overload the quicker the device acts, until with a short circuit the device is almost instantaneous in its action. (Ref. 'Electricity Control', Leonard Andrews.) See TIME-LIMIT DEVICE; also HOBART'S TIME-LIMIT DEVICE FOR CC CIRCUITS.

MAGNETIC BLOW-OUT CIRCUIT BREAKER, a cc circuit breaker in which the final break occurs in a magnetic field. It is a principle in electromagnetics that a conductor carrying a current in a magnetic field will tend to move in a direction at right angles to the field. The arc set up on breaking a circuit constitutes a conductor, and in magnetic blow-out circuit breakers, as generally manufactured, there is an electromagnet, energised by the current to be broken, which produces a field in the neighbourhood of the arc, with the result that the arc moves outwards, and so becomes attenuated and is finally extinguished. As a rule, the main break takes place at ordinary unprotected contacts, which are shunted by subsidiary contacts. These subsidiary contacts then have to carry the full current, and when the current through them is in turn broken the magnetic blow-out comes into operation. (Ref. 'Elek. Mas. Apparate und Anlagen', Dr. F. Niethammer.)

HIGH-VOLTAGE CIRCUIT BREAKER.—High-voltage systems are, in the majority of cases, supplied with ac, and until the general adoption of the oil-break switch with automatic releases various designs of high-voltage fuse were employed. Many of these, however, were unsatisfactory, and, as air-break switches were also often unsatisfactory, the automatic oil-break switch, which combines the functions of both fuse and switch, has now come into general use. Oil-break switches can be provided with overload and with no-voltage releases, and also with reverse releases, though the last named are not in all cases satisfactory (see REVERSE-CURRENT CIRCUIT BREAKER), and any of these can be fitted with time-limit devices. The release coils on the switch can be fed direct from the h pr circuit, but this is not usual at pressures exceeding 2000 or 3000 volts. Beyond this, and often at lower pressures also, current and pressure transformers are generally used to reduce the pressure on the releases, and in the case of reverse releases relays are often employed. See also SWITCH, OIL-BREAK; FUSE.

INTERLOCKED CIRCUIT BREAKER, an automatic circuit breaker so arranged that it cannot be opened or closed unless some other piece of apparatus is in some prearranged position; for instance, a connecting rod is sometimes fitted between the handle of a motor starter and the moving portion of a circuit breaker in such a manner that the latter cannot be closed unless the former is in the 'off' position.

REVERSE-CURRENT CIRCUIT BREAKER (or *Discriminating Cut-out*), an automatic circuit breaker arranged to open a circuit in the event of current flowing in the circuit in the reverse direction to the normal. This is sometimes effected by winding the electromagnet of the circuit breaker with two coils, one connected as a shunt across the main circuit and the other in series with the main circuit, the two coils being so arranged that when the main current flows in the normal direction their effects assist one another, whereas, when the main current reverses, the effects of the coils are neutralised and the breaker opens. This type of cut-out, however, has the double disadvantage that if the current reverses very rapidly, and soon reaches a large value in the opposite direction, it is possible the cut-out may not open at the desired instant, and thereafter the effect of the heavy reverse current will be so great that the breaker will be held in more and more strongly; the second disadvantage being that, should the supply fail, the breaker will open in any case, and have to be reset before the supply can be resumed, though in certain cases, as, for instance, where there is a motor load, this feature is an advantage and not a disadvantage, since the breaker acts as a no-voltage cut-out as well as a reverse-current cut-out.

Reverse breakers, however, can be made positive in their action; that is to say, they can be so arranged that a reverse current exerts a positive pull on the tripping gear, so that the greater the reverse current the

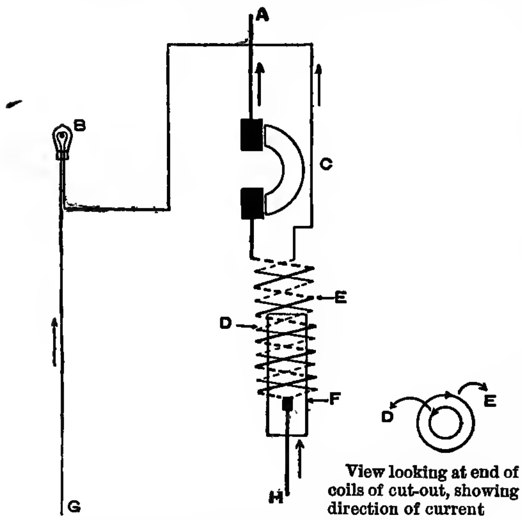


Fig. 1.—Reverse-current Circuit Breaker

A, To + Bus Bar. B, Resistance Lamp. C, Brush of Cut-out. D, Shunt Coil. E, Series Coil. F, Core that trips Cut-out. G, To − Bus Bar. H, To + Pole of Generator.

greater the tripping effect. Many forms of this class of reverse break have been devised, and a typical one is shown in fig. 1, from which it will be understood that in normal working the shunt and series coils tend to neutralise one another, whereas, when the main current reverses, the series coil assists the shunt, the core is lifted up, and the breaker is tripped. It will be noted that a heavy overload in the forward direction would overpower the shunt to such an extent that the breaker would also trip under these conditions.

In another form one of the windings is carried by a small motor armature, and the other by the field magnet of the motor. Nominally the armature is against a stop in one direction, but when the main current is reversed the armature turns in the opposite direction, and so trips the breaker.

It is difficult to design a reverse-current circuit breaker to operate satisfactorily at less than 10 to 15 per cent reverse current, and with some designs the breaker will also open the circuit if a very heavy overload occurs in a forward direction. Neither, however, of these limitations is of great importance in practice, and reverse-current circuit breakers are largely used on modern switchboards.

Reverse circuit breakers are sometimes used on alternating circuits, though in this case they are rather reverse *power* than reverse *current* breakers, seeing that the current reverses rapidly even in normal circumstances. Further, with ac the same principles of action are generally adopted as with cc, *e.g.* the small armature device referred to above is also used on ac circuits, the iron portions, of course, being laminated. The reverse-current feature is often in the form of a *relay*, which closes the tripping circuit of an oil switch.

But the design of a thoroughly satisfactory ac reverse breaker is greatly complicated by the fact that varying pf have to be allowed for, and, as a matter of fact, such breakers are by no means so generally used as their cc prototypes. In some large generating stations the engineers have preferred to rely upon non-automatic or maximum-break oil switches, with what has been called a *discriminating device* to indicate when a generator is taking instead of giving current. Such a device is shown in fig. 2. It consists essentially of a small transformer with two lamps, as shown in the figure, so

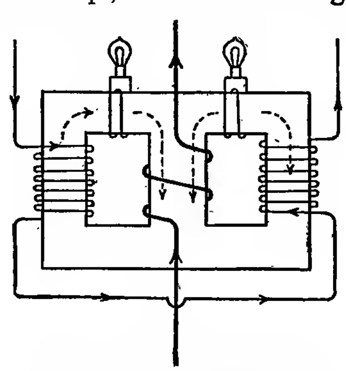


Fig. 2.—Reverse-current Circuit Breaker (Discriminating Device)

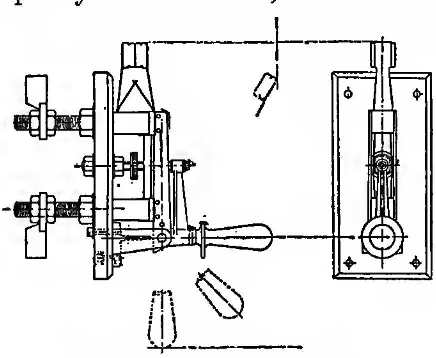
arranged that when the current in the main circuit is in the normal direction relatively to the currents in the potential circuits, one lamp, generally a green one, is kept alight, whereas, when the main current is reversed, the other lamp, a red one, gets the greater pressure and lights up. On seeing the red light the engineer in charge can switch off the circuit, or take any other steps he desires, to put matters right. See also CIRCUIT BREAKER, THERMAL OVERLOAD TYPE; TIME-LIMIT DEVICE. (Ref. 'Electricity Control', L. Andrews; 'Elek. Mas. Apparate und Anlagen', Dr. F. Niethammer.)

[F. W.]

['*Discriminating Cut-out*, a cut-out, usually on a switchboard, for interrupting the circuit when the normal direction of the flow of energy is reversed.'—I.E.C.]

Circuit Breaker, Oil, a switch with the contacts under oil, and arranged to open the circuit automatically. (See 'Automatic Circuit Breaker' under CIRCUIT BREAKER.) Such circuit breakers are used only for ac, owing to the fact that the arc made on opening a cc circuit carbonises the oil, or otherwise alters its constitution to a greater extent than does an ac arc, with the result that the operation of the circuit breaker becomes unreliable and unsatisfactory.

Circuit Breaker, Thermal Overload Type.—A circuit breaker of this type, developed by Morris & Lister, is illustrated in



Circuit Breaker, Thermal Overload Type

the figure. Two contact blocks are fixed rigidly to, but insulated from, the switch arm. They are connected electrically by two parallel strips of suitable metal, each fitted with a steel catchpiece. When the switch is closed the strips are sprung apart over a fixed catch, and the full rated current does not loose the catch. Overload causes the strips to move apart, and the circuit breaker flies off under the action of a spring.

Circuit Breaker, Time-limit Device. See TIME-LIMIT DEVICE.

Circuit Control. See CONTROL, OPEN-CIRCUIT.

Circuit-opening Devices (see also CIRCUIT BREAKERS; SWITCH), devices for opening circuits. They may be either manually or automatically operated. In the 1907 Standardisation Rules of the A.I.E.E. it is recommended that circuit-opening devices be grouped in three varieties, defined as follows:—

(*a*) *Circuit Breakers*, apparatus for breaking a circuit at the highest current which it may be called upon to carry.

(*b*) *Disconnecting Switches*, apparatus designed to open circuits only when carrying little or no current.

(*c*) *Automatic Circuit Breakers*, apparatus for breaking circuits automatically under an excessive strength of current. Such apparatus should be capable of breaking the circuit repeatedly at rated pressure, and at the maximum current which it may be called upon to carry.

Circuit Reversing Commutator. See COMMUTATOR.

Circular Mil, a unit of area used principally in the United States for the measurement of the conducting cross section of wires, stranded cables, &c. It is the area of a circle whose diameter is $\frac{1}{1000}$ in. Thus, in a circular solid conductor the cross section in circular mils is the square of the diameter in thousandths of an inch. The term should be discarded. It is rarely employed outside of the United States.

Circumferential Key. See KEY, CIRCUMFERENTIAL.

Circumferential Speed. See PERIPHERAL SPEED.

Civil Engineering. See ENGINEERING, CIVIL.

Clamping Ear. See EAR, MECHANICAL.

Clamping Rings for Commutator. See RINGS, COMMUTATOR.

Clamps for Windings.—Besides supporting windings against their own weight, and against centrifugal force, it is also necessary to ensure that they shall resist the forces brought into play by the magnetic action of the currents they are to carry, especially on the occasion of a short circuit. Modern alternator windings are therefore securely clamped to one another as well as being stiffly supported from the frame of the machine. See also BINDING BANDS.

Claret-vuillemier System. See SURFACE-CONTACT SYSTEM.

Clark Standard Cell. See CELL, STANDARD.

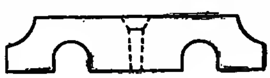
Claw Clutch. See CLUTCH.

Cleaning Stick for Accumulator. See ACCUMULATOR, CLEANING STICK FOR.

Clearance or **Clearance Space,** in dynamo-electric machines the minimum space between the revolving and the stationary member.

This term is more usually employed, when considering the machine mechanically, in contradistinction to *depth of air gap* or *interferric space*, which are used when considering the magnetic properties of the machine. The clearance space may differ from the interferric space. Thus, for instance, when bands are used on the surface of an armature the clearance space is less than the interferric space to an amount equal to the thickness of the bands. See also AIR GAP.

Cleat, a support for conductors or cables, consisting of a bridge piece, generally of wood or porcelain, with one or more grooves in which the conductors are laid. The cleat is fixed to a wall, roof, &c., by a nail or screw (see figure).



Cleat

Cleat Wiring, a system of wiring in a building, yard, &c., in which the conductors are held in position by cleats (which see).

Cleavage, Electrification by.—If a crystal be suddenly broken, the newly separated surfaces are usually found to be electrified, one positively and the other negatively.

Clips, Milking. See MILKING CLIPS FOR ACCUMULATORS.

Clips for Binding Bands. See BINDING BANDS.

Clock Diagrams, diagrammatical constructions employed in the vector analysis of the phenomena of alternating electricity. (Ref. Cramp & Smith's 'Vectors and Vector Diagrams'.) See CIRCLE DIAGRAM.

Clock Meter. See METER, CLOCK.

Clocks, Electric.—These may be classed as (1) electrically controlled, (2) electrically wound and controlled, (3) electrically driven and controlled. In (1) the only electrical feature is the pendulum bob, whose movement is checked or accelerated by an electromagnet connected usually to an observatory clock regulated by star observations of the earth's rotation. (2) In addition to control, the clock is wound from time to time by a small motor. (3) The clock is driven by intermittent and periodic currents from a central controller. In this case no pendulum is required, since the current impulses move the hands forward every second, half-minute, or minute. Wireless electric control was proposed by Sir Howard Grubb (1899), and has been carried out, in Vienna, by Reithoffer and Morawetz up to a distance of 3·72 miles. (Ref. 'Elec.', vol. lix, p. 290, June 7, 1907.)

Clock-spring Brush Holder, a type of brush holder in which the necessary pressure is applied to the brush by means of a clock spring, which, with the aid of a ratchet, may be wound up and adjusted so as to give any brush pressure desired. See also BRUSH HOLDER.

Closed Circuit. See CIRCUIT; CIRCUIT, ELECTRIC.

Closed-circuit Battery. See BATTERY, PRIMARY.

Closed-circuit Control. See CONTROL, OPEN-CIRCUIT.

Closed-coil Armature. See ARMATURE.

Closed Electric-power Rooms. See ELECTRIC-POWER ROOMS.

Closed Laminated Ring. See MAGNET, RING.

Closed Magnetic Circuit. See MAGNETIC CIRCUIT.

Closed Slots. See SLOT; also PARTLY CLOSED SLOTS and TOTALLY CLOSED SLOTS.

Cloth Varnishes.—These are varnishes for coating cloth, and should be quick-baking varnishes. The best consistency at which to use a cloth varnish will depend on whether the cloth is to be treated in sheets or in rolls. For either purpose, the varnish should be used at a fairly low density, and should dry with a good smooth flexible coat. It is usual to give two coatings in opposite directions. Such varnishes may also be used for coating papers, &c. See also CAMBRIC FOR INSULATING PURPOSES.

Clutch.—A clutch is a device for transmitting power between two shafts when they are placed end to end.

CLAW CLUTCH.—The simplest form is the claw clutch, shown in fig. 1. *a* and *b* are the two shafts; *c* and *d* are the two parts of the coupling, each of which has projections which fit into recesses in the other. The part *d* is keyed permanently to shaft *b*, while the part *c* slides on a feather key on shaft *a*, so that it can be drawn out of engagement with *d* when shaft *a* is not required to run. It will be noted that part *c* is provided with a groove *e* to take the jaws of a lever for sliding it along the shaft. This form of clutch can only be put in or out of

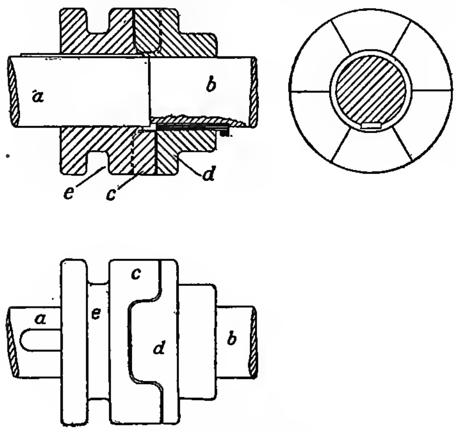


Fig. 1.—Claw Clutch

gear when the driving shaft is stopped or turning very slowly.

Friction Clutch.—Where it is necessary to engage and disengage the driven shaft while the driving shaft is running at full speed, a friction clutch is used, a common and very successful form being that shown in fig. 2. The outer portion of the

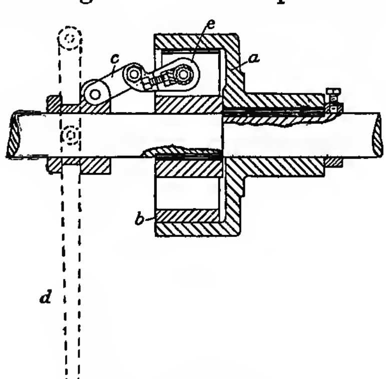


Fig. 2.—Friction Clutch

clutch *a* is keyed on the driven shaft; the inner piece *b* is keyed on the driving shaft. It is turned to fit easily into the outer piece *a*, and is split at its thinnest part. By means of the right- and left-hand screw *e* the piece *b* can be expanded with sufficient force to grip *a* and transmit the driving power. The screw is operated by the lever *d* and the sliding bars and link *c*.

Magnetic Friction Clutch.—In place of the friction surfaces being forced together by mechanical means, they may be drawn together by magnetism, an arrangement which is very convenient when the clutch has to be operated from a distance (see fig. 3). The part *a*, forming an electromagnet excited by the coil *b*, is keyed on the driven shaft, current being conveyed to the coil by means of brushes pressing on the contact rings *c*. The part *d*, forming the armature of the magnet *a*, is keyed on

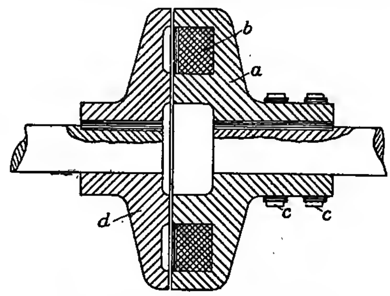


Fig. 3.—Electromagnetic Friction Clutch

the driving shaft. When current is switched on to the coil, the electromagnet is energised, and the two halves *a* and *d* of the coupling are drawn together with sufficient force to transmit the power required. One of the shafts should be allowed sufficient end play to permit the two parts to come into close contact. See also Magnetic Clutch.

[c. w. h.]

Clutch of an Arc Lamp. See Lamp, Arc.

Cm, the preferable abbreviation for *centimeter*.

Coal Bunkers, compartments located above the boilers in electricity supply stations, and serving for the temporary storage of a suitable supply of coal. They thus constitute reservoirs of latent energy. See fig. 1 under Central Station for the Generation of Electricity.

Coal Consumption of Electric Generating Stations. See Central Station for the Generation of Electricity.

Coal Conveyor.—In large electricity supply stations the hourly consumption of coal reaches very large figures. Economies may thus be effected by conveying the coal by automatic devices, termed coal conveyors, from the points where the coal is delivered upon the premises, to the coal bunkers. The conveyors are often so designed and installed as to also be available for conveying away the ash. Coal conveyors are usually either of the belt or the bucket type.

The *belt conveyor* consists of a length of belting extending the entire distance, and suitably supported and guided to permit of carrying the coal in a practically continuous stream on the upper surface of the belt.

The *bucket conveyor* consists of a series of buckets serving a similar purpose. They are usually provided with trap-doors at the bottom, which are automatically tripped open when the buckets arrive at the desired part of the coal bunkers. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Coal-cutter, Electric. See ELECTRIC COAL-CUTTER; MINING EQUIPMENT, ELECTRICAL.

Coal-face Conveyor, Electric. See UNDERGROUND CONVEYOR, ELECTRIC.

Coal-heading Machine, Electric. See ELECTRIC COAL-CUTTER.

Coal-tar Naphtha. See NAPHTHA.

Coal-tar Solvents.—These comprise the distillation products of tar, known commercially as 90-per-cent benzol, 50-per-cent benzol, benzene, and coal-tar naphtha. The nature of these solvents depends partly on the composition of the tar and partly on the method of distillation. They differ from the petroleum solvents by their characteristic odour and chemical composition, containing chiefly hydrocarbons of the benzene series, though hydrocarbons of the paraffin and olefine series are present in small quantities. The terms 90-per-cent benzol and 50-per-cent benzol indicate the proportion of spirit distilling over; below 100° C. the solvent properties of these are considerable, and they are extensively employed in the manufacture of aniline dyes. Benzene and coal-tar naphtha very closely resemble each other, and are sold more or less indiscriminately; the latter, however, usually contains a number of impurities. See BENZENE; NAPHTHA. [H. D. S.]

Coasting, in electric traction, running free without the use of electrical energy for propulsion. The term is applied to a car or train which has been set in rapid motion, and continues to run by virtue of its momentum until its kinetic energy is absorbed by friction, or until it is stopped by the application of the brakes. The motion may also be maintained by gravitation. Also called *drifting*. The translational momentum of a train, when it is travelling at a speed of V miles per hour, is equal to $0{\cdot}0278\ V^2$ w hr per ton weight of train. Rotational momentum adds from 8 to 12 per cent to this, the precise percentage depending upon the dimensions and weights of the wheels and armatures, and on the gearing and speeds. See ENERGY, KINETIC, OF ARMATURES; ANGULAR ACCELERATION OF CAR WHEELS.

Coatings of a Condenser. See CONDENSER, ELECTRIC.

Coaxial Carbons. See CARBONS, ARC LAMP.

Code Wire. See WIRE, CODE.

Coefficient, Specific Utilization. See UTILIZATION COEFFICIENT, SPECIFIC.

Coefficient, Steinmetz. See HYSTERESIS COEFFICIENT.

Coefficient of Absorption.—Referring to transmitted light, this term denotes the ratio of the intensity of the light absorbed by the medium during the process of transmission, to the intensity of the light falling upon it.

With reference to reflected light, the term is used to denote the ratio, expressed as a percentage, of the intensity of light absorbed by the reflecting surface during the process of reflection, to the intensity of the light falling upon the surface before reflection.

Coefficient of Adhesion. See ADHESION, COEFFICIENT OF.

Coefficient of Diffused Reflection. See COEFFICIENT OF REFLECTION.

Coefficient of Electrostatic Induction. See DIELECTRIC CONSTANT.

Coefficient of Hysteresis. See HYSTERESIS COEFFICIENT.

Coefficient of Linear Expansion.—This should preferably be defined as the increase in length of 1 m of a given material when its temperature is increased by 1° C. The coefficent of expansion of copper is about 0·000017; consequently, if a bar of copper is 1 m long at some temperature—say 20° C.—then, when its temperature is increased by 1° C.—say to 21° C.—its length is increased to 1·000017 m. For temperatures ranging from 0° to 100° C. the approximate coefficients of expansion of several metals frequently employed by electrical engineers are as follows:—

Lead ...	0·000028	Copper ...	0·000017
Aluminium	0·000023	Iron and steel	0·000012
Brass ...	0·000019	Platinum ...	0·0000089

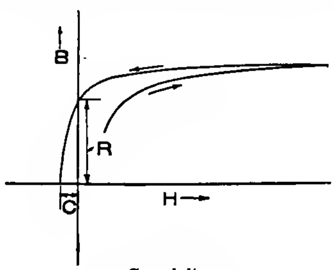
Thus for a given increase of temperature a bar of lead will increase in length by nearly four times as great an amount as a bar of platinum of equal length.

Coefficient of Reflection, the percentage ratio of the intensity of the light reflected from a surface to the light originally striking that surface. This definition is applicable to surfaces which disperse the light striking them, in an irregular fashion, the term being then sometimes referred to as *the coefficient of diffused reflection.*

Coefficient of Traction. See TRACTION, COEFFICIENT OF.

Coefficient of Transmission, the percentage ratio of the intensity of the light transmitted by a medium to the intensity of the original light impinging upon it.

Coercivity, the reverse magnetic field required to reduce a mass of iron which



Coercivity

R, Retentivity. C, Coercivity

has been highly magnetised, to a state of zero magnetisation. See fig.

Cogging Effect, a term applied to the dead-point tendency at starting, due to the necessary use in induction motors, of a finite number of slots.

Coherer, an imperfect electrical contact, or series of contacts, such that their resistance is reduced by the application of voltage, even if the duration of the application is only one-millionth of a sec. There are many theories of coherer action. It may be due to welding (Lodge), *i.e.* to softening of the metals through heating and consequent interpenetration of their particles; to electric force, causing attraction, and therefore closer contact; or to some property of the non-conducting film between the conductors. Hughes discovered (in 1879) that his microphone was sensitive to electric as well as to mechanical disturbances. In particular, he found that a tube containing metallic particles, indicated, by its variations in resistance, the occurrence of sparks at an induction coil some hundreds of yards away and not connected to the tube. The phenomenon was rediscovered later by Lodge, Calzecchi, Onesti, Branly, and others.

An infinite variety of forms of coherer is possible. Thus the contact may be between a point and plane (Lodge), two crossed rods, a tripod on a plane, a needle and mercury under oil, a razor-edged steel wheel and mercury under oil (Lodge-Muirhead); a large number of metal filings in an insulating tube with electrodes (Hughes, Branly, &c.); a small quantity of very fine filings between plane electrodes less than 1 mm apart (Marconi); a drop of mercury between plane electrodes (Solari). All these and many others have been used in wireless telegraphy.

The use of a coherer is that it records, by its change in resistance, an electric action too rapid to be itself observed. *Decoherence,* or the return of the instrument to its sensitive state, is usually effected by a slight mechanical shock. Some coherers are *self-decohering,* or rather are decohered by the continued action of the local battery; in some cases the resistance rises instead of falling, when the voltage is increased.

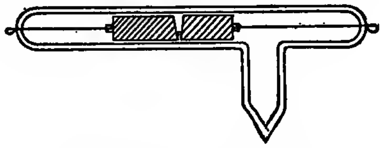
[J. E-M.]

['*Coherer,* in wireless telegraphy, a device employed at the receiving station, and consisting essentially of an imperfect contact, or system of contacts, such that its resistance is altered on the reception of a signal.'—I.E.C.]

Coherer, Carborundum.—It has been found (Ref. Dunwoody, U.S.A., Patent 837616/1906) that a crystalline mass of carborundum, when supplied with electrodes, acts as a detector of electric currents of very hf. This property is due (see G. W. Pierce, 'Physical Review', vol. xxv, p. 31, 1907) to the fact that a crystal of this substance conducts more easily in one direction along the axis than in the opposite direction. The crystal is therefore a rectifier, and transforms an ac into a series of unidirectional impulses which may be detected by a telephone or other current instrument. Currents up to 1 amp may be carried by a crystal with a sectional area of a few sq mm. It is advisable to platinise one or both ends of the crystal. The telephone and crystal may be used with or without a battery in circuit.

[J. E-M.]

Coherer, Filings, type of coherer developed from the *Branly tube.* The Marconi type (see fig.) consists of a glass tube of about 4 mm bore, with silver plugs about 0·5 to 1·5 mm apart, their faces being usually slanted to give a wider gap at one side than at the other. Between them a small quantity of very fine nickel filings, with or without a very small percentage of silver, is placed. By turning the tube the filings



Marconi's Form of Filings Coherer

are brought to the narrower or wider part of the gap, and the sensibility of the coherer may thus be altered as required.

Coil, Active. See Active Coil.

Coil, Armature, one of the groups of windings for an armature core.

Coil, Auxiliary. See Coil, Compensating; Coil, Compounding.

Coil, Choking, a reactive coil introduced into an ac circuit to regulate the current flowing. Such coils are often provided with an arrangement for adjusting the reactance or choking effect, which consists in making the core movable relatively to the coil. Sliding the core into the coil increases, and withdrawing it decreases the reactance. The reduction of the pressure due to the action of a choking coil depends on the pf of the load relatively to that of the coil. When these are equal, the choking effect is a maximum. With a non-inductive load, the load emf and the emf across the choking coil are practically in quadrature, hence the latter must be relatively large to produce a given reduction of current. See also Regulators, Potential; Choking Effect; Coil, Kicking.

['*Choking Coil*, a coil with so great a self-induction that its impedance depends chiefly on the self-induction rather than upon the resistance.'—I.E.C.]

Coil, Compensating (Dynamo-electric Machinery), a coil acting as or forming part of a compensating winding (which see).

On cc machines the term is sometimes but wrongly used as synonymous with the coil on an interpole.

Coil, Compensating (Meters), an auxiliary coil used in cc energy meters to compensate for solid friction at low loads and on starting (see Compounding Coil), and in mercury motor-meters to compensate for fluid friction at high loads (see Meter, Ferranti and Meter, Hookham). In the former it forms the low-load adjustment, and in the latter the high-load adjustment. See also Coil, Compounding.

Coil, Compounding, an auxiliary coil used in cc w hr meters (Thomson and oscillating types) to neutralise, as far as possible, the effect of friction, especially at light loads, and on starting when the magnetic effect of the main-current or field coils is weak. The coil consists of a few turns of insulated wire in series with the armature (or two such coils in series are used), and so placed that the flux produced by the pressure current flowing in it augments the main-current field and exerts a supplementary driving torque on the armature. This additional torque always exists, as the armature circuit is continuously connected across the supply mains. The coil is usually made adjustable, so that the effect it produces can be varied to suit the conditions of the installation, and on account of the variable nature of friction. It is usually so adjusted that the meter starts with about 1 per cent of its maximum capacity. It forms the light-load adjustment in cc energy meters.

Coil, Damping. See Damping Coil.

Coil, Dead. See Dead Coil.

Coil, Diamond-shaped Form-wound. See Coil, Form-wound.

Coil, Dummy. See Dead Coil.

Coil, Earth, a coil of large diameter, often used as a standard for magnetic measurements by rotating same through an angle of 90° in the earth's field. The amount of the change of flux through the coil is equal to the density of the 'earth's field' resolved at right angles to the plane of the coil, multiplied by the area of the coil.

Coil, Eickemeyer. See Coil, Form-wound.

Coil, Exploring, a coil wound round a magnetic circuit for the purpose of measuring any change in flux through the magnetic circuit by means of the quantity of electricity sent through an external circuit of known resistance. This quantity can be measured either by a ballistic galvanometer or by a flux meter. See Coil, Earth.

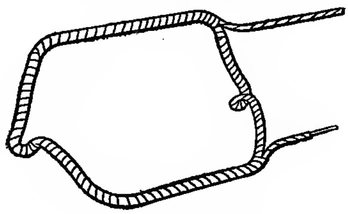
Coil, Field, the spool of insulated wire put on to the field magnet of a dynamo or motor to carry the magnetising current. See also Coil, Magnet.

Coil, Flat, a coil the axial length of which is short compared to its diameter.

Coil, Form-wound, a coil prepared on a former (see WINDING, FORMING AND SPREADING MACHINERY); also termed *former-wound coil.*

DIAMOND-SHAPED FORM-WOUND COIL.—Often a form-wound armature coil in its final stage, is approximately in plan a six-sided figure, and has sometimes been called *diamond-shaped.*

EICKEMEYER COIL, a form-wound coil, designed by Eickemeyer in 1888, and which



Eickemeyer Coil

gives a very short over-all length of winding. See fig.

PANCAKE COIL, a flat former-wound coil used in the construction of the early smooth-core rotating armatures of alternators. The term is also sometimes applied to the flat separately insulated unit coil used in modern high-pressure transformers.

Coil, High-pressure.—This is that one of the two coils in a sp transformer (or in each phase of a multiphase transformer) which is provided for the high-pressure electricity.

Coil, Induction, two or more coils of insulated wire, wound and placed so that their mutual induction is large. To obtain a high pressure, one of the coils is of great length, and comprises many turns of fine wire; the other is short, and of but few turns of thick wire. A core of iron wires is employed where the frequency of the currents is not high. If an ac is supplied to the primary, the coil acts as an ordinary transformer; as, however, the pressure in the secondary winding is proportional to the rate of change of the primary current, it is usual to employ an intermittent rather than an ac, to produce which some type of *break* is used. This is a mechanism actuating a pair of contacts which close the circuit and open it alternately. The break may be electromagnetic (*hammer break*), mechanical (*mercury break*), or electrolytic (*Wehnelt break*). In coils built to give high pressure, the primary may consist of 20 or 30 meters of thick wire, and the secondary of 10 to 15 miles of fine wire. The secondary should be wound in thin sections, each insulated by impregnated paper, the paper being perpendicular to the core. In modern coils (*e.g. Kreisler's*) the natural vibrations of the secondary and primary circuits are *equifrequent*, and therefore in resonance, which gives much greater efficiency than can be obtained otherwise. See also 'Induction-coil Commutator' under COMMUTATOR; COIL, SPARK; COIL, RUHMKORFF.

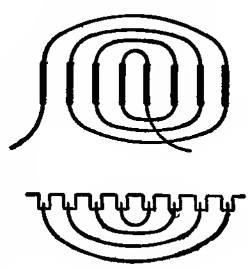
Coil, Kicking, a term sometimes used to denote a small reactance or choking coil. It is particularly used in connection with multi-contact switches on variable-pressure transformers, where a small coil is connected between the two halves of the split contact finger to prevent short-circuiting when moving from contact to contact. When thus employed, it is sometimes termed a *preventive coil.* See CHOKING EFFECT.

Coil, Lap. See LAP COIL.

Coil, Magnet or Field, the coil of wire or strip which is fitted on to the pole of a dynamo machine, and which carries the cc which excites the magnetic circuit. See also COIL, FIELD.

Coil, Magnetising. See MAGNETISING COIL.

Coil, Multiple, a coil so designed that it occupies more than one pair of slots. (See COIL, SINGLE.) It may be double, triple, quadruple, &c. A multiple coil is illustrated diagrammatically in the fig.



Multiple Coil

Coil, Pancake. See COIL, FORM-WOUND.

Coil, Preventive. See COIL, KICKING.

Coil, Reactance, a term synonymous with *choking coil* (which see), and as frequently used. See CHOKING EFFECT.

Coil, Repeating. See REPEATER.

Coil, Resistance.—A convenient form in which to make up resistances of known value, consists in winding 'Manganin', 'Eureka', or other high-resistance wire on a bobbin, and in bringing the ends out to suitable terminals. The wire is commonly doubled before winding, in order to eliminate inductance, and the bobbin is preferably made of brass to ensure that the temperature of the coil shall be the same all through. See also AGEING OF RESISTANCE COILS.

Coil, Retardation. See RETARDER.

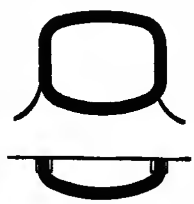
Coil, Ribbon, a coil wound with flat strip the width of which is great compared to its thickness.

Coil, Ruhmkorff, a term formerly widely employed for induction coils (see COIL, INDUCTION), for the reason that some of the very earliest induction coils were constructed by Ruhmkorff. See also COIL, SPARK.

Coil, Search, a coil used to determine the change of flux at any point in a magnetic field. Usually used in conjunction with a ballistic galvanometer or fluxmeter. See also COIL, EXPLORING; COIL, EARTH.

Coil, Sectional, a coil wound in such a way as to decrease the difference of potential between adjacent layers. The total number of turns required is equally divided into several sections, and each section is wound on a separate former or otherwise insulated from the other sections.

Coil, Single, the group of turns subtending one pole forming one element or unit of the winding for an electric machine, so designed that it occupies a single pair of slots, as shown in the fig.



Single Coil

Coil, Spark, a type of transformer with a very high ratio of transformation. The primary winding, usually on a straight iron core, consists of a few hundred turns of thick wire, and the secondary consists of many thousands of turns of fine wire. The secondary must be highly insulated, and is usually wound in separate sections between disks of paper which have been dipped in some suitable insulating varnish. The primary current is taken either from an ac circuit or from a cc supply. In the latter case an interrupter must be placed in the circuit in order to cause the variations necessary to produce induced currents in the secondary. This interrupter is an intermittent contact, the simplest being the hammer break, which is actuated by the varying magnetism of the core of the coil. Other forms of break are independently driven. The principal are the mercury dipping break with reciprocating motion, the mercury turbine break, and the electrolytic Wehnelt break. A condenser is shunted across the spark gap. For a long time its function was not understood; it is, however, now clear that the shunt (condenser) circuit forms an oscillating circuit of hf, and therefore that it causes a far more sudden drop of pressure to take place at the contact connected to the near end of the primary than would otherwise take place. The result is a sudden change of magnetic flux in the coil and the generation of high pressure in the secondary. Coils are now made in which the natural frequencies of the primary and secondary circuits are equalised, thus giving a much greater effect. See also COIL, INDUCTION; INDUCTION-COIL COMMUTATOR; COIL, RUHMKORFF; COIL, TESLA. [J. E-M.]

Coil, Spiral. See SPIRAL COIL.

Coil, Tesla, an ironless transformer, for use with currents of very hf. The number of turns in both primary and secondary coils is small, the secondary being wound in two portions, one over each end of the primary. The ratio of transformation of the pressure does not depend directly on the ratio of the numbers of turns in the primary and secondary, but on the exactness of the approximation to equality of the natural vibrations of the two circuits. The coil is usually sunk in oil to increase the insulation. The primary circuit consists of a small number of turns, say 20, of thick wire, with a condenser and spark gap, the two sides of the last being connected to the source of supply (a transformer or induction coil). The secondary may consist of about 200 turns of gutta-percha-covered wire wound on two bobbins, which are placed near the ends of the primary. Between primary and secondary there is a glass tube. See COIL, INDUCTION. [J. E-M.]

Coil, Trembler. See TREMBLER COIL.

Coil and Plunger.—When an iron rod or tube is suspended with one end near the mouth of a helix, carrying current, it experiences a force tending to draw it into the helix. If the iron plunger is supported by a spring, or from the arm of a balance, its position may be used as an indication of the current, the whole apparatus constituting an ammeter, when properly graduated. A well-known form is Lord Kelvin's amperemeter, in which a balance arm is used.

Coil Ends, the inactive parts of an armature coil, *i.e.* the parts which do not 'cut' magnetic lines.

Collecting Rail. See THIRD-RAIL ELECTRIC RAILWAY.

Collecting Shoe, an iron block carried by links beneath or at the side of a railway car, and rubbing on the third rail, to collect the current for operating the car or train. In the case of an under-contact third rail the shoe is arranged to press upwards against its lower surface. See also RING, COLLECTOR.

Collector, the device which, by sliding or rolling contact with an overhead conductor or a third rail, establishes electrical connection between the apparatus on an electrically propelled vehicle and the source of supply of electricity. The device is more apt to be called a collector when of the bow type, where the contact is sliding. *Collector* is, however, as thus used, practically synonymous with *trolley*, under the definition of which several varieties are defined. The term *collector* is also used to designate a part of a dynamo, for which see RING, COLLECTOR.

['*Collector*, a sliding piece which makes contact and collects the current from a fixed part of an electrical apparatus, or vice versa.'—I.E.C.]

Collector Gear for Electric Cranes. See CRANE, ELECTRIC.

Collector Ring. See RING, COLLECTOR.

Colloidal.—Substances are said to exist in the *colloidal* as opposed to the *crystalline* condition when they are prepared in a finely divided state, in which they possess little diffusing power and their particles exhibit a tendency to collect together in gelatinous masses. The substance is then available in an adhesive and plastic condition, which renders it easily convertible into any desired shape. This condition has recently been utilised by Kuzel in the manufacture of glow-lamp filaments. It has been believed that the better understanding of the attributes and behaviour of metals in the colloidal state will greatly influence developments in the manufacture of filaments for incandescent lamps. (Ref. B.P. No. 28154, 1904.)

Colloidal Process of Manufacturing Tungsten-lamp Filaments. See LAMP, INCANDESCENT ELECTRIC.

Colour Photometry. See PHOTOMETRY.

Columbia Rail Bond. See BOND.

Comb, a line of fine conducting points attached at right angles to a conductor. Its purpose is to facilitate the discharge of high-pressure electricity from the points of the comb to another comb or conductor through the air gap, which would form an insulator for currents of low pressure. A comb is used as 'lightning arrester' to provide a path to earth where telegraph and telephone wires enter a building. It is also used as a collector on electrical machines of the friction type.

Comb Pole. See POLE, COMB.

Combined Efficiency. See EFFICIENCY.

Combined Switch and Fuse, a switch to one terminal of which a fuse is connected so that the switch and the fuse form one piece of apparatus. Double-pole combinations of this kind are largely used on circuits up to, say, 100 or 200 amperes at pressures up to, say, 250 volts. For larger currents and higher pressures it is desirable to have separate fuses of a more special design than those that can easily be combined with a switch.

Combined Winder and Spreader. See WINDING, FORMING, AND SPREADING MACHINERY.

Commercial Efficiency. See EFFICIENCY.

Common Battery Switchboard. See SWITCHBOARD, COMMON BATTERY.

Commutating Field. See FIELD, COMMUTATING.

Commutating Poles. See INTERPOLES.

Commutation, the act of collecting current from a cc machine, which involves the reversal of the direction of the current in each coil of the armature every time it passes under a set of brushes. The theory of commutation is somewhat complicated, and for a complete study the reader is referred to the standard treatises on the theory of the dynamo. A fairly complete résumé of the sources of trouble in commutation is given in an article by Miles Walker in 'The Electric Journal' of May, 1907.

FORCED COMMUTATION.—In shifting the brushes forward towards the neighbouring pole tip, or in providing commutating poles, the coil undergoing commutation is brought under the influence of a flux which induces an emf in the coil opposed to the direction in which the current has been previously flowing. This facilitates the sparkless collection of current, and is opposed to what may be called the "natural" method of commutation, in which the current is reversed by the action of the brush passing over the segment.

Frequency of Commutation.—Between the instant at which one commutator segment commences to pass under the brush and that at which the preceding segment leaves the brush on the other side, the current in the coil between the two segments is completely reversed in direction. Taking this operation as corresponding to half of one complete cycle of current variations in the coil, we may readily obtain the time of one complete commutation period, supposing such a complete cycle ever took place. Having this, we may then, of course, readily calculate the frequency of this cycle. This 'frequency of commutation' is often of the order of 250 complete cycles per sec, and is obtained as follows:—

Let d = diameter of commutator in mm,
b = breadth of brush in mm,
s = speed of commutator in rps,

then frequency of commutation

$$= \frac{\pi d s}{2b}.$$

The figure for the frequency of commutation is used in the calculation of the 'reactance voltage' of an armature coil.

Neutral Axis or Diameter of Commutation, the position at which the brushes are set. See Armature Reaction.

Commutation Zone, the region, expressed either in electrical angular measure or in the number of commutator segments, over which the brushes are moved in order to obtain good commutation between no load and full load. It should, however, be noted that in modern dynamo-electric machinery of good design, brush movement is rarely employed. In many machines even of recent design, it is still necessary.

Sparkless Commutation, commutation taking place without any sparking at the brushes of a dynamo or motor.

Sparking may be so violent as to be clearly visible at the brush when the machine is in operation, or it may be so slight that the spark is hidden under the brush, and that its occurrence can only be detected by its effect in marking the commutator segments. In order that commutation may be truly described as sparkless, neither of these effects must be present. For practical calculations relating to commutation, Hobart's 'Dynamo Design' should be consulted.

Commutator.—I. As usually applied, a commutator is a device used on cc machines for conveying the current from the armature in such a way that when collected by the brushes it becomes unidirectional. From the view of a commutator shown in fig. 1 it will be seen that it consists of a number of copper segments, S, mounted radially. Connections are made from the various segments to points on the armature windings, and when the brushes are allowed to bear upon the commutator, the current is thus always collected from a portion of the armature which is, for the time being, in a given position with regard to the magnet poles. Fig. 1 illustrates the commutator of a multipolar generator, and shows the method of securing the copper segments in place.

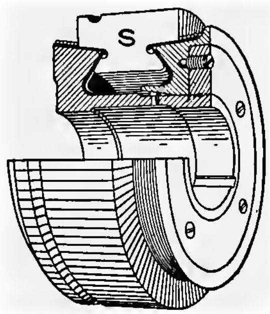


Fig. 1.—Commutator

In 'Electric Power and Traction', Davies defines commutator as follows: 'The device fixed on the shaft of a cc dynamo which rectifies the ac generated in its armature and sends them out to the circuit in an uniform direction'. See Commutation.

II. Sometimes the word *commutator* is taken as synonymous with *key*—a key the manipulation of which, reverses the current in a circuit. See Key, Pohl's Commutator.

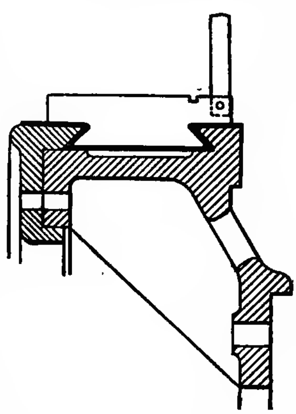


Fig. 2.—Ventilated Commutator

['*Commutator*, an apparatus for reversing the direction of a current in any circuit. In a dynamo or motor, that portion on which the brushes press and collect or deliver the current.'—I.E.C.]

Ventilated Commutator.—Air is frequently circulated through a commutator in order to maintain it at a suitably low temperature. One type of ventilated commutator is shown in fig. 2.

TOPLIS VENTILATED COMMUTATOR.—In this design, which is the subject of British

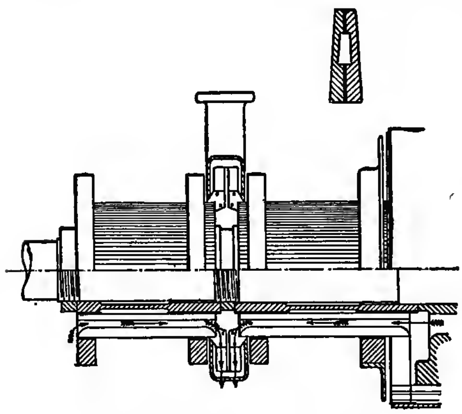


Fig. 3.—Toplis Ventilated Commutator

Patent No. 7255 of 1906, and which is illustrated in fig. 3, air is circulated through longitudinal recesses in the commutator segments.

SIDE-BEARING COMMUTATOR.—A commutator, the bearing surface of which is vertical. See WALKER COMMUTATOR.

THREE-PART COMMUTATOR.—This is an obsolete construction, consisting of a tube cut into three segments. The segments are connected to the ends of three coils placed at 120° around a two-pole armature. The advantage over the two-part commutator was that a more *uniform* unidirectional current was obtained.

SPLIT-RING COMMUTATOR.—In the earliest form of commutator, a complete ring was cut into two equal pieces, which were mounted on a wooden cylinder. The arrangement is now used only on toy motors and on induction-coil commutators. See TWO-PART COMMUTATOR, and INDUCTION-COIL COMMUTATOR.

TWO-PART COMMUTATOR. — The simplest form of commutator consists of a tube cut into two parts, each part being connected to one end of a single-coil armature, as indicated in fig. 4. Its only use nowadays is on toys. It is often referred to by teachers because it affords a simple means of explaining the elementary principles of commutation.

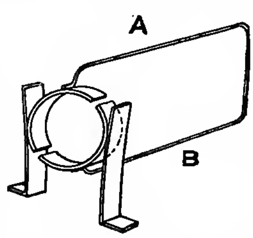


Fig. 4.—Two-part Commutator

To state this principle briefly, it will be noticed from the diagram that whatever side of the coil (A or B) is under the influence of the magnetic pole which may be situated on the left side of the diagram, the current is being conveyed via the portion of the commutator connected to that side of the coil, to the left-hand brush. Consequently the current which appears at that brush is unidirectional.

CROSS-CONNECTED COMMUTATOR, a commutator in which bars separated around the periphery by twice the polar pitch, are connected together by butterfly connections, thus equalising the pressure under similar sets of brushes and ensuring that equal currents shall be collected by all brush sets of the same sign. See CROSS CONNECTIONS.

INDUCTION-COIL COMMUTATOR.—Literally a commutator is a device for commuting or altering the direction of a current. Fig. 5

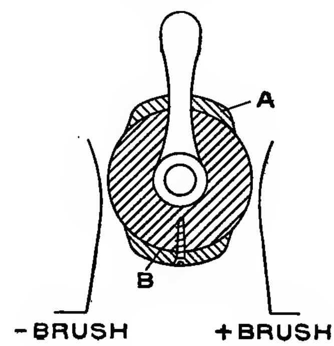


Fig. 5.—Induction-coil Commutator

shows the arrangement which is used on an induction coil for altering the direction in which a cc is turned on to the primary coils.

The word *commutator* is also applied to a device placed on the shaft of a petrol or gas motor for timing the sparking in the cylinders. The device is simply a *contact maker*, and should be known as such.

Modern commutators for dynamo-electric machines are generally of the V-ring pattern for moderate-speed machines and of the shrink-ring pattern for high-speed machines.

A *V-ring commutator* is shown in fig. 6, from which it is seen that the segments are held by annular end rings which project into V-shaped recesses in the segments.

A *shrink-ring commutator* is shown in fig. 7.

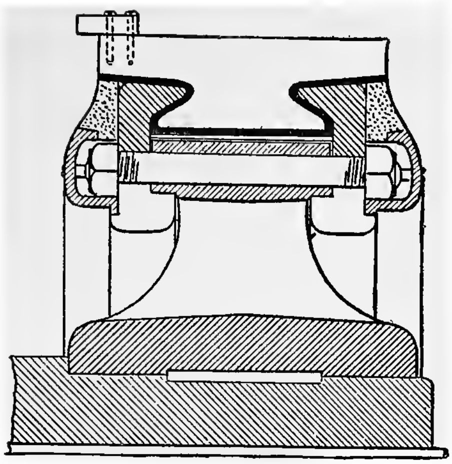


Fig. 6.—V-ring Commutator

In this type, the segments are retained by external shrink rings.

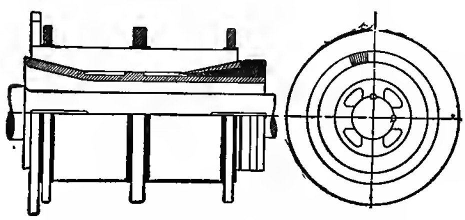


Fig. 7.—Shrink-ring Commutator

Circuit - reversing Commutator. — In laboratories commutators of an altogether

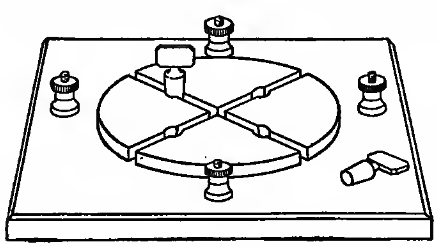


Fig. 8.—Circuit-reversing Commutator

different type are employed for affording convenient means of reversing the current in a circuit. These may be termed *circuit-*

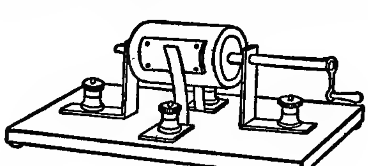


Fig. 9.—Two-part Circuit-reversing Commutator

reversing commutators. A four-part plug commutator is shown in fig. 8, and a two-part drum commutator in fig. 9.

See also Commutator Segment. (Ref. Livingstone's 'The Mechanical Design and Construction of Commutators'.)

Commutator, Lug of, the thin strip of copper which is soldered or riveted to a commutator bar and carries the current to the armature windings. Formerly often termed a Commutator Riser.

Commutator, Walker. See Walker Commutator.

Commutator, Wearing Depth of.—The friction of the brushes on a commutator wears away the copper, sometimes so unevenly that it has to be turned true. Commutator bars are therefore designed so that there is a considerable depth to spare, and they may then be turned many times before being completely worn out. Consulting engineers in their specifications usually require a minimum wearing depth.

Commutator Bar, the piece of copper strip of which a commutator is built. See Commutator Segment.

Flat Bar on Commutator, a bar which, being of a softer nature than its neighbours, or as the result of some property of the design (of the machine), wears away more quickly than the rest of the commutator.

High Bar on Commutator, a bar on a commutator which stands up higher than its two neighbours, due generally to one of two causes, viz. the insulation in the V rings has become soft and has given way, or the copper of which the bar is made is of a harder quality than that of its neighbours, and consequently has not worn away so quickly.

A high bar, of course, conduces to bad commutation. See Commutation.

Commutator Brackets, the brackets cast with the main spider, and on which the commutator shell is mounted or fixed. See Spider.

Commutator Brush. See Brush.

Commutator Building Ring. See Ring, Commutator.

Commutator Clamping Ring. See Ring, Commutator.

Commutator Grinder, an emery-wheel attachment which may be fixed on to one of the brush studs of a cc machine, and is used for grinding the commutator true, thus avoiding the necessity of dismantling the machine.

Commutator Insulation, Effects of Oil on.—It has been estimated that as much as 90 per cent of breakdowns in commutating machines are due to oil on the commutator. Be this as it may, it is certain that lubricating oil produces a very deleterious effect on commutator insulation. For one thing, it affords an adhesive surface to which dirt and carbon dust can cling, thus promoting leakage. Again, the oil is carbonised on the commutator face by sparking, and so forms a bridge from one segment to the other. This results in more sparking, followed by the burning away of the mica segment. In the pit so formed, which is a common object in broken-down machines, carbon dust, oil, and carbonised oil accumulate, resulting in the end in a short circuit of very low resistance and a complete burnout of the shorted coil. It is an open question whether the oil exerts a direct influence on the micanite by dissolving out the binding material, but pure mica segments are less subject to the effect above described than are segments of built-up mica. Whatever material is used for the insulation of a commutator, it will be wise, however, to so design the oil-throwing and catching gear that no oil from the bearings can possibly find its way on to the commutator. See a series of correspondence in 'Elec. Rev.' for Nov., 1906; also 'The Insulation of Electric Machines', Turner and Hobart, pp. 126, 155.

Commutator Losses. See Losses, Commutator.

Commutator Motor. See Motor, Commutator.

Commutator Motor Meter. See Meter, Commutator Motor.

Commutator Ring. See Ring, Commutator.

Commutator Riser. See Commutator, Lug of.

Commutator Segment, a piece of copper strip, tapered and punched to a form such

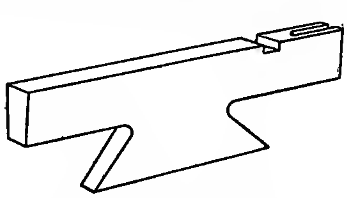


Fig. 1.—Segment of Commutator

as is roughly indicated in fig. 1. On the under side, the segment is of dovetail shape, in order that it may be gripped by end rings which hold the bar securely to the commutator spider. The armature side of the segment has a slit cut to receive the risers, which go to the armature coils, and a circumferential groove is often cut just near where the risers leave the bar, to indicate the position beyond which it is not appropriate to set the brushes, as shown in fig. 1.

Buckling of Commutator Segments.—In long commutators, either in clamping up

Fig. 2.—Buckling of Segment of Commutator

or under the action of centrifugal force when running, or again due to expansion if the commutator overheats on load, the segments are likely to bend or buckle in the centre. To prevent this, such commutators are either provided with steel rings, which are shrunk on outside over a layer of insulation, or with a central dovetail, as indicated in fig. 2.

Interlocking Commutator Segments, segments constructed to fit into one another

Fig. 3

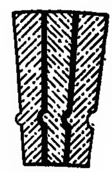


Fig. 4

Interlocking Commutator Segment

for the purpose of resisting the tendency to bulge outward under the influence of centrifugal force. Amongst such constructions may be mentioned the *Burke Interlocking Commutator Segment* and the *Brush Company's Interlocking Commutator Segment.* See figs. 3 and 4.

Commutator Shell, the casing which forms a support for the commutator segments, *i.e.* the rim of the spider or other mounting arrangements in which the commutator is built.

Commutator Spider.—Besides being mounted from brackets on the main machine spider, the commutator support is itself sometimes made in the form of a spider which is mounted either upon a sleeve extension of the main hub, or directly on the shaft. See Spider.

Commutator Stones, stones employed for the purpose of grinding and smoothing commutators. By the occasional application of commutator stones, the slight ridges often caused by sparking may be smoothed off, thus saving the expense of turning down the commutator.

Commutator Truing Device, a tool permitting of truing the commutator, without requiring its removal from the machine. One type consists of a grinding wheel equipped with suitable clamps by means of which it can be fastened to the rocker arm, or to the frame of the machine.

Compensated Alternator. See ALTERNATOR, COMPOUND-WOUND; 'Heyland Polyphase Generator' under GENERATOR.

Compensated Series Motor and **Compensated Repulsion Motor.** See MOTOR, COMMUTATOR; SINGLE-PHASE MOTOR.

Compensated Voltmeter. See VOLTMETER.

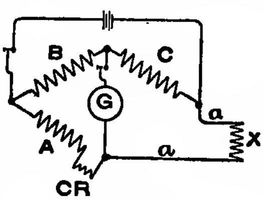
Compensated Wattmeter. See WATTMETER.

Compensating Coil. See COIL, COMPENSATING.

Compensating Field, the magnetic field due to a compensating coil. Magnetic field due to a compensating pole.

Compensating Poles. See INTERPOLES.

Compensating Resistance.—When it is desired to eliminate the effect of the resistance of some necessary part of a circuit, a resistance may sometimes be introduced into some other part of the circuit, such that its effect is always equal and opposite to that of the first resistance.



Compensating Resistance

Thus, in the diagram, if it is required to measure the resistance of X by Wheatstone's bridge and eliminate the influence of the leads, a resistance CR equal to the leads may be introduced into arm A, or into C if A is equal to B. See BRIDGES. [L. M.]

Compensating Winding, a winding adapted to neutralise or compensate for some one component of the magnetic flux due to the main winding, and thus alter the phase relation of current to emf. Compensating windings are provided in many types of sp commutator motors to neutralise the inductance component of the armature flux and thus improve the pf. See also COIL, COMPENSATING.

Compensation, the neutralisation of a mmf or of an emf by another mmf or emf. Compensation is usually employed either to obtain a high pf (which see) or improved commutation. See also CONDUCTIVE COMPENSATION; INDUCTIVE COMPENSATION; SINGLE-PHASE MOTOR.

Compensator, a term sometimes used instead of *auto-transformer*. See AUTO-TRANSFORMER.

THREE-WIRE AC COMPENSATOR denotes a compensator or transformer used to balance a three-wire ac system (see fig. 1). A is a two-wire alternator supplying a three-wire system whose neutral wire N is tapped from

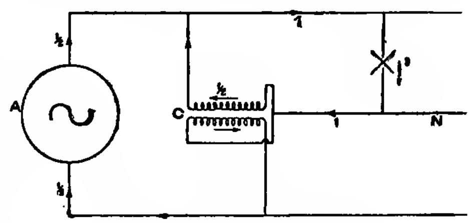


Fig. 1.—Three-wire ac Compensator

a three-wire compensator C. The latter consists of a 1:1 transformer connected with both coils in series, the neutral being connected to their junction. It is evident that the neutral wire will be maintained at a potential midway between that of the outers, and that any unbalanced current I which returns along N divides equally between the two coils, one-half of it flowing through the generator. Such a compensator may be used at any point on an alternating three-wire system where there is a considerable out-of-balance current to be taken care of. See TRANSFORMER, THREE-WIRE; also TRANSFORMER, ADAPTER.

THREE-WIRE COMPENSATOR.—The term is sometimes used to denote a balancer or re-

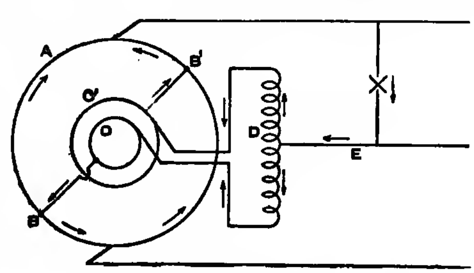


Fig. 2.—Three-wire cc Compensator

actance coil connected to slip rings on a cc generator for deriving a neutral wire for three-wire service. The arrangement is the invention of Dobrowolski (see fig. 2). See also DOBROWOLSKI THREE-WIRE DYNAMO.

In fig. 2, a cc generator (or motor) A has its armature tapped at two points, B and B′, and connected to slip rings C C′. A compensator or reactive coil D, between the two halves of which there is minimum magnetic leakage, is connected to C and C′ by brushes, and has its middle point tapped and connected to the neutral wire E. It is clear, from the symmetry of the arrangement, that the centre point of the coil must always be approximately midway in potential between that of the brushes, and hence any unbalanced current will return into the armature, dividing equally between the two halves of the coil. The coil carries an alternating magnetising current sufficient to generate a c emf, and also a superposed cc. The latter, however, produces no magnetising effect on the core, as its direction is opposite in the two halves of the coil.

The arrangement forms a cheap and effective substitute for a balancer set, but lacks the adjustable properties of the latter, as the I R drop in the compensator causes a slight unbalancing which can be compensated only by a small neutral-wire booster, or by some similar arrangement.

There are various modifications of the arrangement. Thus more than two slip rings may be used. The compensator windings, however, should always be arranged so that the magnetising effect of the neutral current is self-neutralised in the windings, as otherwise saturation occurs, causing a very heavy alternating magnetising component.

[The I.E.C. employs the term *compensator* solely as a synonym for *auto-transformer* (which see).]

Compensator, Adapter. See TRANSFORMER, ADAPTER.

Compensator, Balancer. See TRANSFORMER, ADAPTER.

Compensator Potential Regulators. See REGULATORS, POTENTIAL.

Component Current. See CURRENT, COMPONENT.

Component emf. See ELECTROMOTIVE FORCE, COMPONENT.

Composite Loop. See LOOP OF ARMATURE COIL.

Compound Die. See DIE.

Compound Dynamo. See COMPOUND-WOUND DYNAMO.

Compound Excitation. See EXCITATION.

Compound Magnet. See LAMINATION OF MAGNET.

Compound Motor. See COMPOUND-WOUND MOTOR.

Compound Winding. See WINDING, COMPOUND.

Compound-wound.

['*Compound-wound.*—A generator or motor is said to be compound wound when the magnetic field is excited partly by series and partly by shunt coils, or by independently-excited coils.'—I.E.C.]

Compound-wound Alternator. See ALTERNATOR, COMPOUND-WOUND.

Compound-wound Dynamo, a cc generator which is provided with both shunt and series windings on the field magnets. The excitation of the field magnets on light load is produced wholly by the shunt winding; as the external resistance is diminished, causing the dynamo to take up load, the current flowing to the external circuit through the series winding increases the excitation, thus compensating for the loss of pressure due to the resistance of the armature and for the demagnetising effect of the current in the armature winding. The proportions of shunt and series winding may be so designed as to produce practically constant pressure between the terminals at all loads, or an increasing or slightly falling terminal pressure with increasing load. The shunt winding may be connected directly to the brushes (*short-shunt dynamo*) or to the main terminals (*long-shunt dynamo*). See 'Continuous-current Generator' under GENERATOR.

Compound-wound Generator. See GENERATOR; ALTERNATOR, COMPOUND-WOUND.

Compound-wound Motor, an electric motor for cc, which is provided with both series and shunt windings on the field magnets. If the connections are the same as in a compound-wound dynamo, the series winding will oppose the shunt winding, and will thus reduce the starting torque, though it will improve the speed regulation. Such a motor is said to have a *differential compound winding.* (See WINDING, DIFFERENTIAL.) More usually it is desired to increase the torque at starting, and the connections of the series winding are such that it assists the shunt. The fall in speed, with increase of load, is increased in this case.

Compound-wound Relay, a relay, or electrically controlled circuit-closing key, in which the field-magnet windings are compound, *i.e* contain two or more separate circuits. See RELAY.

Compounding. See EXCITATION.

Compounding, Automatic, methods of winding generators so that the terminal pressure remains constant (or varies in a predetermined manner), under fluctuations of load, without any alteration of the resistance of the exciting circuit either by hand or by means of auxiliary apparatus.

Compounding Coil. See COIL, COMPOUNDING.

Compressed Gas as an Insulator.—The dielectric strength of a gas rises rapidly with increased pressure. Its dielectric resistance when compressed, is very high. Hence Professor Ryan has proposed compressed air for use as a commercial insulator of high quality. The apparatus to be insulated is enclosed in a strong metal casing, hermetically sealed, into which dry air is pumped at h pr. Other gases have also been suggested, of which carbon dioxide is one of the most promising, as its dielectric strength is some 20 per cent better than that of air. See DIELECTRIC STRENGTH. (Ref. Ryan, 'Electric Club Journal', July, 1905.)

Concatenated Motor. See CASCADE MOTOR.

Concatenation. See CASCADE MOTOR.

Concentrated Field Winding. See WINDING, CONCENTRATED FIELD.

Concentrated Winding. See WINDING, CONCENTRATED.

Concentration of Iron Sands, Magnetic. See SEPARATION OF ORES.

Concentration of Ores, Electromagnetic and Electrostatic. See SEPARATION OF ORES.

Concentration of Potential.—When the windings of electrical apparatus are switched abruptly upon an ac line, the end turns for the first instant (*i.e.* before there has been time for the permanent distribution of potential throughout the entire winding to take place) are subjected to a potential out of all proportion greater than are the turns more remote from the terminals of the winding. High-pressure transformers afford a suitable instance of this occurrence. To protect the winding from harmful effects from this concentration of potential, reactance coils may be connected in series with the windings, or the end turns may be especially well insulated.

Concentric Cable. See CABLE, CONCENTRIC.

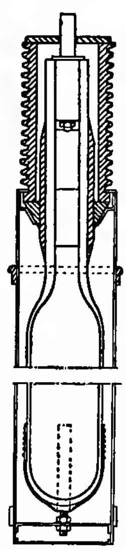
Concrete-steel Line Poles. See LINE POLES.

Condensance. See REACTANCE.

Condenser. See CONDENSER, ELECTRIC; CONDENSER, STEAM.

Condenser, Barometric. See CONDENSER, STEAM.

Condenser, Electric, a system of two conductors separated by a dielectric, which, between the conductors, is thin in comparison to their area. A difference of pressure applied to the conductors thus produces positive and negative charges which face one another across the dielectric. The thinner the latter, and the greater its specific inductive capacity, the greater is the density of the charge for any given pressure. The arrangement is sometimes called an *electrostatic accumulator*. The capacity of a condenser is its charge, expressed in suitable units, when the applied pressure is unity. (See CAPACITY.) The dielectrics most commonly used are glass—in the form of plates, tubes, or jars—waxed paper, mica, and air. If only low pressures are used, an *electrolytic condenser* may be convenient, in which a thin film of an insulating compound of aluminium, deposited electrolytically on an aluminium plate, forms the dielectric, while the plate and liquid are the conductors. The capacity of an electrolytic condenser is very great, owing to the thinness of the film, but for the same reason, the condenser will not stand high pressures.



Moscicki Condenser

A condenser will transmit an alternating, but not a continuous current. Any given condenser transmits ac the better, the higher their frequency. The capacity of a condenser also varies slightly with the frequency.

MOSCICKI CONDENSER, a pattern of Leyden jar properly mounted for engineering purposes. The dielectric is a long, thin, glass tube, coated electrochemically with silver and copper, and thickened at the parts where the electrical stresses are greatest. The arrangement is shown in the figure. The tube is also surrounded with a liquid consisting of a mixture of glycerine and water to prevent breakage from unequal heating. The jar is enclosed in a metal case of either block tin or brass, and the whole condenser is hermetically sealed to prevent leakage of the liquid. The condenser may be used in any position, and is not sensitive to vibrations or slight blows. See 'Giles Electric Valve' under RECTIFIER; SWITCH, CONDENSER.

COATINGS OF A CONDENSER, the conducting plates or metallic films forming the conducting parts of a condenser.

STANDARD CONDENSER, a condenser whose capacity has been carefully adjusted to some known value, usually one-third or one-half of 1 mfd. A short-circulating key is fitted, in order to eliminate any residual charges.

ADJUSTABLE CONDENSER, a condenser in which the capacity may be varied by altering the relative position of the plates. This is usually done either by sliding the plates along parallel grooves, or by mounting one set on a shaft while the others are in the form of quadrants into which the first set may be more or less introduced. Adjustable condensers are also made up, like a resistance box, in units and fractions.

ROTARY CONDENSER, a name sometimes given to any form of synchronous motor which, by over-excitation, takes an idle current from the line, leading the impressed emf by 90°. The term has been applied to such a machine because its action in this particular is similar to that of an electrostatic condenser. The properties of the two are, however, not similar in other ways. If we try to represent such a motor by an equivalent condenser, we find that the capacity of the latter depends upon the applied pressure, since an increase of pressure at the terminals of the motor, decreases the current. Hence the reactance of the motor is negative, while that of a condenser is positive.

Use is made of this property to compensate for an inductive load such as that caused by induction motors. A single synchronous motor, independent of the ordinary transforming apparatus, is sometimes specially installed for the purpose.

Condenser, Electrolytic. See CONDENSER, ELECTRIC.

Condenser, Steam.—The condenser is an important part of the equipment of an electricity supply station, and permits of economies far in excess of those attainable with non-condensing plant. Particularly is this the case where the prime movers are steam turbines, since the steam consumption of turbines is very dependent on the exhaust pressure. A condenser is an apparatus in which heat is extracted from the steam entering the condenser from the steam turbine. The greater the percentage of the heat which is extracted from the steam, the lower will be the pressure in the condenser and the higher will be the efficiency of the plant. The means by which heat is extracted from the steam, vary with the type of condenser. At present, all types of steam condenser are based on the principle of bringing cold water into proximity to the steam. Heat flows from the steam to the water, condensing the former and heating the latter, which passes from the condenser and is recooled, or else replaced by a fresh supply of cool water, in order to repeat the process. Types of condenser are described in detail in many textbooks, and the subject is treated from the broad, practical, and economical standpoint in chap. v of Hobart's 'Heavy Electrical Engineering'.

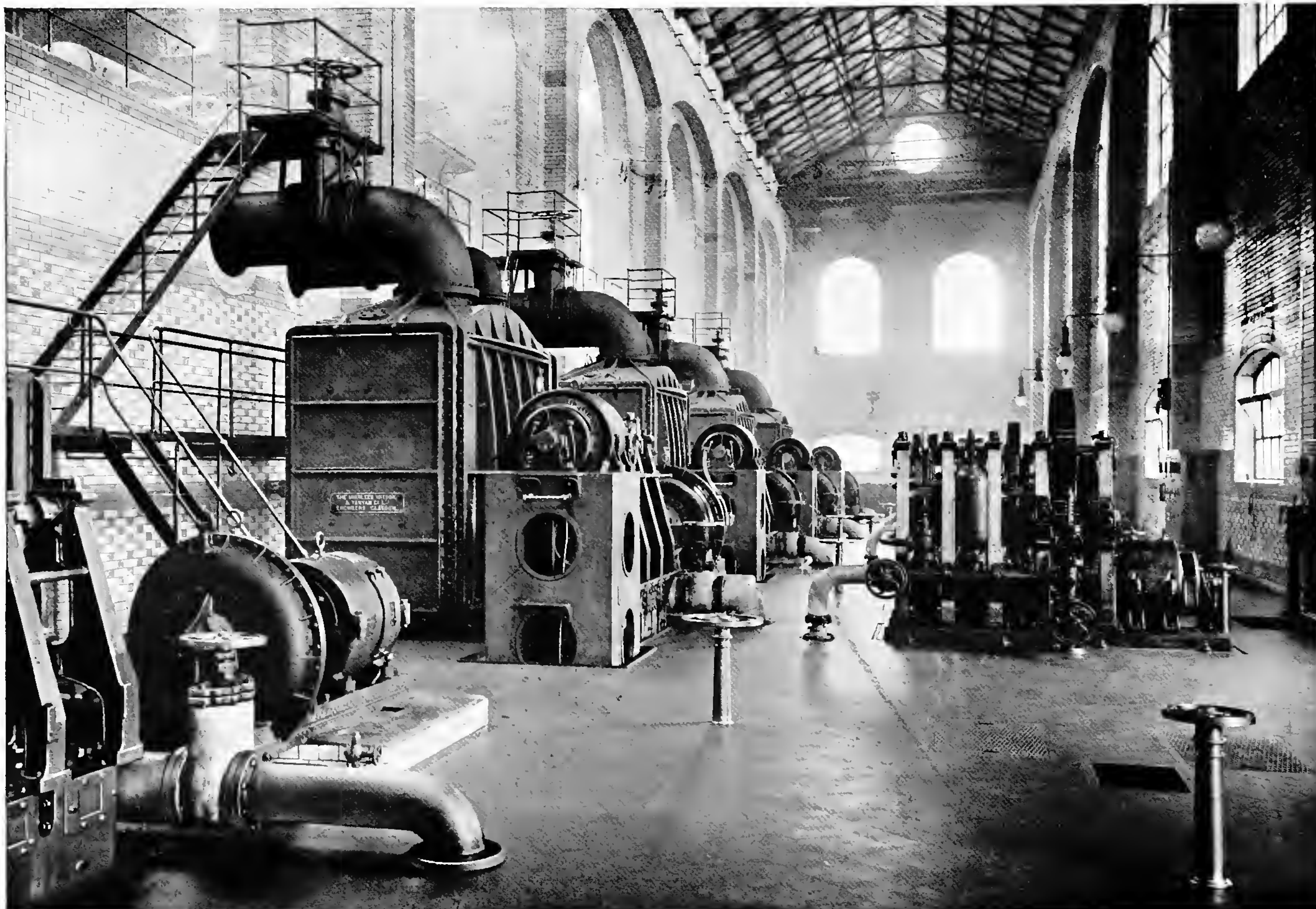
The four principal types of condenser are:

1. The Jet Condenser.
2. The Surface Condenser.
3. The Ejector Condenser.
4. The Evaporative Condenser.

1. In the *jet condenser* the exhaust steam from the engine (or turbine) is led into a chamber, when it comes into contact with jets of cold water.

2. In the *surface condenser* the steam is led into a chamber in which is a bank of pipes through which cold water is circulated.

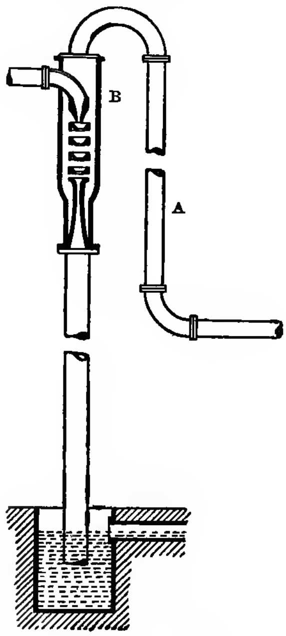
3. In the *ejector condenser* a jet of water is delivered past the mouth of the exhaust pipe and entrains the steam. A *barometric condenser* is an improved form of ejector condenser, in which the exhaust steam pipe A (see fig.) passes to a height of about 36 ft (corresponding to more than the height of the water barometer), before entering the ejector chamber B. Here the condensing water (from a pump or from an additional 15 ft head) flows through a conical nozzle and annular conical guides to the contracted neck of an exit pipe, which then has a fall of at least 34 ft to the hot well. Between the nozzle and the exit, the water comes in contact with the exhaust steam present in the chamber, condenses it, and carries the



SURFACE CONDENSING INSTALLATION AT THE GLASGOW CORPORATION TRAMWAYS POWER STATION
(The Mirrlees Watson Company, Ltd., Glasgow)

[To face p. 118.

water formed on through the exit. Air and non-condensing vapours in the exhaust are also withdrawn; but in most barometric condensers an air pump is added. Those with no air pump are more often called *siphon condensers*, but they are of the barometric type. The height of the exit pipe also prevents water being 'sucked' into the engine



Barometric Condenser

exhaust pipe when the apparatus cools after use.

4. In the *evaporative condenser* a continuous supply of water trickles over the surface of a bank of tubes through which the steam flows. See also TOWER, COOLING.

Condenser Current. See CURRENT, CONDENSER.

Condenser Switch. See SWITCH, CONDENSER.

Condenser Transmitter. See TRANSMITTER.

Condenser-type Bushing. See BUSHING, CONDENSER-TYPE.

Condensing Electroscope. See ELECTROSCOPE.

Condensive Load. See TRANSFORMER, VOLTAGE DROP IN.

Conduct, To, to be traversed, or to be capable of being traversed, by an electric current. See CONDUCTOR.

Conductance, a constant associated with any particular conductor, intended to express its power to conduct. The ratio of the current in a conductor to the difference of pressure between the electrodes, the current and pressure being supposed constant, and the current not subject to any emf in the conductor. The conductance is accordingly the reciprocal of the resistance of a conductor. See RESISTANCE, ELECTRIC; ADMITTANCE.

The unit of conductance is the reciprocal of the unit of resistance, and the term *mho* has been proposed as the name of the unit, to correspond with the ohm. (See OHM.) Thus a circuit having a resistance of 10 ohms would be said to have a conductance of 0·1 mho. The unit, however, is not largely used, as that of resistance appears to fulfil practical requirements.

When several conductors are connected in multiple to the same source of constant pressure supply, the final current in each is independent of the current in the others. It follows, therefore, that the conductance of a system of conductors so connected is the sum of the conductances of the several conductors.

In ac problems the meaning of the term *conductance* has been extended to represent the energy component in the reciprocal of the impedence. If r be the resistance and x the reactance of an apparatus, the conductance g is

$$g = \frac{r}{r^2 + x^2}.$$

In this expression the conductance g is the quantity by which the applied emf must be multiplied to obtain the energy component of the current.

If E is the emf, then the total current is

$$E \times \frac{1}{\sqrt{r^2 + x^2}},$$

and the energy component is

$$E \times \frac{1}{\sqrt{r^2 + x^2}} \times \frac{r}{\sqrt{r^2 + x^2}},$$

$$= E \times \frac{r}{r^2 + x^2},$$

or

$$E \times \text{conductance}.$$

(Ref. 'Alternating Current Phenomena', Steinmetz, § 40.) See also CONDUCTIVITY; CONDUCTOR. [F. W. C.]

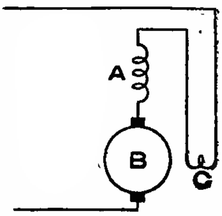
Conducting Varnish, Transparent. See VARNISH, TRANSPARENT CONDUCTING.

Conduction, the mode of transmitting electrical energy particularly associated with the phenomenon of the electric current. See CONDUCTOR; CONDUCTIVITY; CURRENT, ELECTRIC; CONDUCTANCE.

Conduction, Atmospheric. See ATMOSPHERIC ELECTRICITY.

Conduction, Electrolytic. See ELECTROLYSIS.

Conductive Compensation, a means of effecting compensation in which the current is conveyed to the compensating coil by conduction. A conductively compensated series motor is illustrated diagrammatically in the figure. See COMPENSATION; INDUCTIVE COMPENSATION; SINGLE-PHASE MOTORS.



Circuits of Conductively Compensated Series Motor

A, Compensating Coil. B, Armature. C, Field Coil

Conductive Coupling. See COUPLING, CONDUCTIVE.

Conductive Discharge. See DISCHARGE, CONDUCTIVE.

Conductivity, the property of matter which tends to eliminate differences of electrical potential in a body; the particular property of a conductor. As a measurable quantity, the word *conductivity* is used in comparing substances with one another with reference to their power to conduct. It is, properly, the amount of current which flows in an exactly specified piece of the substance per unit difference of potential between the electrode, thus being synonymous with *specific conductivity*, or *specific conductance.* It is then numerically the reciprocal of resistivity (which see), but is rarely used in this sense. It is more generally used in making comparisons between substances, the conductivity being then expressed as a *fraction* or *percentage* of that of some standard substance. See CONDUCTION. [F. W. C.]

Conductivity Bridge. See BRIDGES.

Conductor, a substance through which an electric current is able to flow. For practical purposes the word is restricted to substances, such as metals, in which perceptible currents flow without the application of excessive emf. Substances through which only very minute currents are able to pass, such as glass and indiarubber, are known as nonconductors or insulators (which see). Between conductors and insulators lie a large number of substances which are known as poor conductors or poor insulators, according to the point of view incident to the matter under consideration.

The word is also used to denote bodies made of conducting substances. In particular, the connecting wires, cables, &c., employed to give the desired direction to electric currents in generators, motors, instruments, distributing systems, &c., are known generally as *conductors.* The substance principally used for such conductors is copper. [F. W. C.]

In the definitions accompanying the 1908 Home Office Regulations for Electricity in Factories and Workshops, *Conductor* is defined as 'an electrical conductor arranged to be electrically connected to a system'. See CONDUCTIVITY; CONDUCTION.

Conductor, Active, a conductor forming part of an active coil, or the active part of the conductor of a coil.

Conductor, Armature, an element of an armature winding. The term is usually applied to the straight part of a single conductor, *i.e.* the part parallel to the shaft. Sometimes, however, it is used to denote a conductor and the end connections corresponding to it. Still less frequently, the entire winding is designated the *conductor, e.g.* in insulation tests the resistance is measured 'from conductor to core'. For 'Eddy Currents in Armature Conductors' see EDDY CURRENT.

Conductor, Earthed.—This term is defined as follows in the 1907 Wiring Rules of the I.E.E., which relate to the supply of electricity at 1 pr not exceeding 250 volts:—

> 'A *conductor* is said to be earthed when it is connected to the general mass of the earth in such a manner as will ensure, at all times, an immediate and safe discharge of electrical energy'. See EARTH.

Conductor, Equivalent, an imaginary conductor of such dimensions and material that its resistance is equal to that of the combination to which it is said to be equivalent.

Conductor, Neutral. See NEUTRAL CONDUCTOR.

Conductor, Outer.—In the 1907 Wiring Rules of the I.E.E., which relate to the supply of electricity at 1 pr not exceeding 250 volts, the term is defined as follows:—

> 'The *outer conductors* of a three-wire system are those between which there is the greatest difference of potential'.

This definition is followed by a note to the following effect:—

'This specialised use of the word *outer* must not be confused with the non-technical use of the word when applied to the external conductor of a concentric main which physically surrounds the other conductor or conductors of such main'.

See also THREE-WIRE SYSTEM; NEUTRAL CONDUCTOR.

Conductor, Prime, the large conductor to which are fixed the collecting devices in a friction electric machine.

Conductor, Ribbon.—A ribbon-shaped conductor is occasionally used for short lengths of bare overhead conductors which are worked at very high current densities, since it offers a greater radiating surface than a round wire of equal cross section. Also, for the windings of electric machines and transformers, ribbon copper offers considerable advantages in many cases. The space factor is good, and the windings can be arranged with but one row of conductors, placed vertically above one another. This not only simplifies the winding, but reduces to a minimum the pressure between adjacent wires.

Conductor, Screened. See SCREENED CONDUCTOR.

Conductor, Twin, a conductor with two cores insulated from each other and from outside contact. The most common form of such conductor is *twin flexible*. See also CABLE, FLEXIBLE. (Ref. 'Modern Electric Practice', vols. ii and iii.)

Conductor, Uninsulated.—In the 1907 Wiring Rules of the I.E.E., which relate to the supply of electricity at l pr not exceeding 250 volts, this term is defined as follows:—

'A conductor is said to be *uninsulated* when, although not earthed' (see CONDUCTOR, EARTHED), 'no provision is made by the interposition of a dielectric, or otherwise, for its insulation from earth'.

Conductor Rail. See THIRD-RAIL ELECTRIC RAILWAY.

Conductors, Bare.—Defined by the Verband Deutscher Elektrotechniker as such overhead conductors located outside any building as have no metallic sheathing or other protective covering. Installations in the open, in gardens, courtyards, in buildings, &c., are not included, so long as the distance to the protecting point is not greater than 10 m. (Ref. 'Journ.I.E.E.', vol. xli, p. 167.) See BARE.

Conductors, Bunching, in Protective Tubing. See BUNCHING OF CONDUCTORS IN PROTECTIVE TUBING.

Conductors, Hidden.—This expression is employed in the 'Phœnix Fire Office Rules for Electric Light and Electric Power Installations' to designate 'conductors passing between floors and ceilings, inside roofs, behind wainscotting, or otherwise out of sight in buildings'. Such conductors are required to 'be enclosed in approved metal or other fireproof tubes, except the circumstances be such that metal tubes would not be desirable'. These rules further stipulate that *hidden conductors* shall not be used (except by special permission) for 'carrying a current of over 250 volts'.

Conductors, Jointing. See JOINT; JOINTING ALUMINIUM CONDUCTORS.

Conductors, Network of. See NETWORK OF CONDUCTORS.

Conductors, Overhead, electrical conductors, insulated or not insulated, located at a height above the ground, and suitably supported at intervals.

In this country the most general type of overhead conductor is the trolley wire for electric tramways or railways. (See TROLLEY WIRE.) Long transmission lines are but rarely met with in Great Britain, and overhead conductors for ordinary lighting and power supply are not encouraged.

The Board of Trade have, however, issued 'Regulations for Overhead Wires', in which it is stated that when overhead conductors are contemplated, the scheme must be submitted to the Board and the plans approved by them. In designing such a line the factors of safety must be at least 5 for the line, 10 for wooden poles, and 6 for poles of other materials; the wind pressure must be taken as 50 lb per sq ft, and no extra allowance need be made for snow; the minimum height of the conductors above ground is 22 ft, and 25 ft where ht mains are carried above streets; the line of the conductors must not cross a street at an angle of less than 60° with the line of the street. Since the advent of power-distribution companies, and the consequent necessity for carrying mains over a considerable distance in more or less open country, overhead lines have become more frequent than they were a few years ago.

On the Continent, and still more in America, where water power in large quantities is available, and long-distance transmissions a necessity, overhead lines are largely adopted. Wooden poles have heretofore usually been employed (see 'Wooden Line Poles' under LINE POLES), spaced 50 to the mile, though steel towers with much larger spans are now coming into extensive use. See 'Steel-tower Transmission Line' under TRANSMISSION LINE.

The conductor is either of *hard-drawn copper* or hard-drawn aluminium. When of

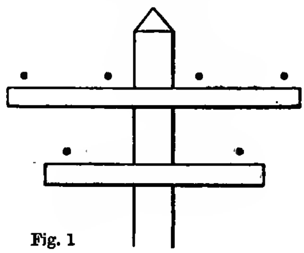


Fig. 1

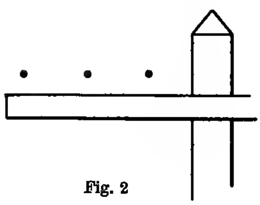


Fig. 2

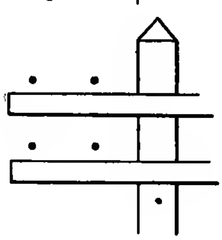


Fig. 3

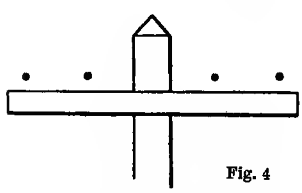


Fig. 4

Figs. 1 to 4.—Overhead Conductors

copper the conductor is either solid or stranded, and has a tensile strength of about 60,000 lb to the sq in (42 kg per sq mm). Many engineers prefer, for mechanical reasons, not to work with an area less than about 25 sq mm, which corresponds to a diameter of approximately 6 mm or 0·22 in. Apart from mechanical considerations, the area of the conductor depends upon the loss allowed in the line, which, in turn, has to be carefully selected, so as to give the most economical working of the line, taking into account the annual cost of the loss of energy in the line, and also the interest and depreciation on the capital outlay and the cost of repairs. 10 to 15 per cent loss of energy in the line is sometimes met with in 20,000-volt transmissions, while for long distances, in spite of the higher pressures, still larger percentage drops are often tolerated. In this connection, it should be noted that, owing to the *inductive effect* of the line, the percentage drop in volts over the conductors is appreciably greater than the corresponding percentage loss of energy; for instance, with a No. 0 conductor, worked at 60 cycles per sec, and with a pf of 0·90, the *apparent resistance* is about 40 per cent greater than the ohmic resistance, assuming a distance of 18 in (46 cm) between the conductors. The greater the distance between conductors the greater the inductive effect. There is also a *capacity effect* which tends to neutralise the inductive effect, but it is in most cases in practice so small as to be negligible, so far as pressure drop on overhead lines is concerned, though it may play a most important part in connection with surges on the line, due to switching operations or to lightning effects. The apparent resistance is also affected by the so-called *skin effect*, due to the current crowding to the outside of the conductor, but again the result is almost negligible in practice, so far as overhead lines are concerned, at the frequencies now generally adopted.

Overhead conductors are strained up between the poles, so that the sag or deflection may not be excessive. The tension when the temperature is lowest, and the stress therefore greatest, should not exceed one-quarter of the breaking stress, or, say, 15,000 lb per sq in (10 or 11 kg per sq mm). The majority of textbooks on the subject, give tables showing variation of sag with temperature, sag for different tensions on different lengths of span, &c.

The distance between conductors varies with the pressure, being roughly 18 to 24 in (46 to 60 cm) for pressures up to 20,000 volts, 36 in (about 90 cm) up to 30,000 volts, and above that, 48, 60, and 72 in (1·2 to 1·8 m) for higher pressures, as, for instance, on the Missouri River Power Company's lines, where the pressure is 57,000 volts, and the three-phase wires 78 in (about 2 m) apart. The majority of power transmissions are three-phase, though a consi-

TERMINAL H POLE ON 10,000-VOLT TRANSMISSION LINE
(WITH DIVIDING BOXES AND CHOKING COILS)
(Callender's Cable and Construction Company, Ltd.)

[*To face p. 122.*

derable number are two-phase with four conductors. Though it is desirable to have two or more separate pole lines, some distance from one another, to minimise the risk of a shut down of the plant, it is common to have two or more circuits on the same line of poles. Three-phase lines are generally arranged in equilateral triangles (see fig. 1), or three in a row on one cross arm (see fig. 2). Two-phase lines are generally as shown in fig. 3 or in fig. 4.

To equalise the inductive effects of the conductors of a circuit upon one another, or of the conductors of one circuit upon those of another circuit, the conductors are transposed at intervals relatively to one another. See TRANSPOSITION OF CONDUCTORS IN TRANSMISSION SYSTEMS.

Overhead conductors operating at comparatively low pressures are frequently used in private installations, in works, collieries, and so forth. In these cases, bare hard-drawn copper or aluminium wires are generally employed, though, where the action of impurities in the atmosphere has to be guarded against, the wires are protected with a special covering (see CABLE, AERIAL), or with a special paint or varnish compound. Where there is a possibility of human beings coming in contact with the conductors, they should be fully insulated rubber cables; but it should be borne in mind that if the span is a normal one—say of 40 yd (36 m)—the conductors should be hard-drawn to ensure their tensile strength being sufficient. In this connection it may be mentioned that, according to the 'Board of Trade Regulations for Overhead Wires', any overhead conductor for the supply of electrical energy must be efficiently insulated wherever it is within 5 ft measured horizontally, or 7 ft measured vertically, from a building.

Aluminium conductors, for equal lengths and conducting capacity, are cheaper than copper conductors when they do not require to be covered with insulating material. For their relative advantages see ALUMINIUM.

[F. W.]

(Ref. 'Electric Power Transmission', Louis Bell; 'Electrical Engineers' Pocket-book', Foster; 'Distribution of Electrical Energy', Snell; 'Modern Electric Practice', vol. iii.)

Conductors, Transposition of, in Transmission Systems. See TRANSPOSITION OF CONDUCTORS IN TRANSMISSION SYSTEMS.

Conduit.—A conduit is a tube or pipe in which electric conductors are laid. See also CONDUIT SYSTEM; CONDUIT, INTERIOR.

EARTHENWARE CONDUIT. — For street work the conduits are of earthenware or of some bituminous compound, and may consist of a single pipe or of groups of pipes moulded together. See also CONDUIT, UNDERGROUND.

STEEL CONDUIT.—For use inside buildings the tubes are of steel, enamelled to protect them from rust, and preferably screwed at the ends, so that good metallic contact is obtained from tube to tube. The tubes are often laid in the plaster of the walls, since it is sometimes considered preferable that they should be out of sight, and are connected to earth to prevent the possibility of shock should the insulation of the electric conductors become defective. [C. W. H.]

Conduit, Interior, conduit or piping arranged to carry electrical conductors inside buildings. Originally *bitumened paper tubing* was in use, made in sections which were joined by metal ferrules; but while this forms an insulating duct for the conductors, it does not offer any great mechanical protection. Various forms of metal tubing have therefore been introduced, notably by the Simplex Steel Conduit Company, from which circumstance the name *simplex tubing* has become popularised. These metal tubings generally consist of a thin sheet-iron or sheet-steel piping, with the seam open, or brazed, or galvanised over. The tubing is generally coated inside and out with an insulating paint, and the joints are made by springing the scraped ends of the sections into suitable metal ferrules. It is, however, questionable if these joints make good contact after a time, if moisture is present, as it is desirable they should do, and undoubtedly a more substantial construction is secured if screwed junctions are employed. The latest practice is to employ solid tubes and screwed joints.

Steel piping with a bitumenised paper lining and with screwed joints is also sometimes used when a specially substantial and secure protection for the conductors is desired, though this is, of course, much more expensive than ordinary light tubing with plain socket joints.

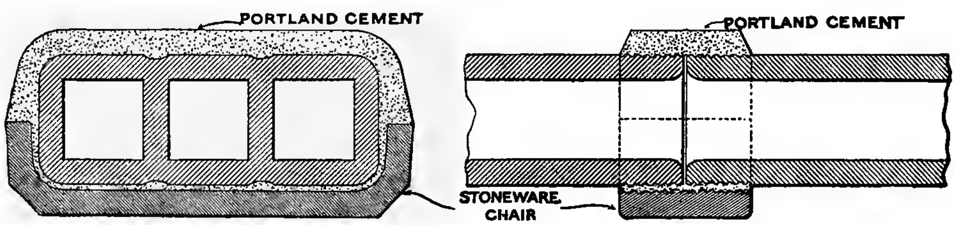
All tubing systems have specially designed boxes for tee joints, ceiling-rose connections, switch connections, and so forth, also special *inspection boxes*, both for straight runs and for bends. See INSPECTION FITTINGS.

With all tubing systems care must be taken to avoid abrading the conductors when pulling them into position. As a rule, not more than two wires, a positive and the corresponding negative, are run in a single duct. Tubing is exceedingly popular for installation work, and indeed shares with wood casing a pre-eminence in such work. See also CONDUIT; CONDUIT SYSTEM; WIRING SYSTEMS. (Ref. 'Electric Wiring, Fittings, Switches, and Lamps', Maycock.)

Conduit, Underground, conduits laid underground for the reception of electric cables. The conduits may be (1) of iron, (2) of earthenware or bitumen, (3) of iron lined with cement.

Wrought-iron pipes were originally used to carry cables, but it was found that the iron was rapidly eaten away by moisture, and that electrolytic action was set up if any electrical leakage occurred from the cable, hence the use of wrought-iron pipes is now largely superseded.

Cast-iron pipes are frequently used as ducts, since they do not rust so rapidly as wrought-iron pipes. The joints should be leaded in order that they may not leak, and that the pipes may be truly in line, and that there



Figs. 1 and 2.—Doulton Earthenware Duct for Cables

shall be a continuous electrical connection. Should the joints not be electrically perfect, the pipes do not form a continuous earthed circuit, and any leakage from the conductor within them may spread through the ground from an isolated pipe or pipes to the detriment of the pipes themselves, and possibly also of neighbouring pipes, owing to electrolytic action. The pipes are cast singly, owing to the difficulty of casting them in groups and making effective joints.

Earthenware ducts are largely employed. They are fairly cheap, can be made in groups, and, being composed of insulating material, are not subject to electrolytic action. Figs. 1 and 2 show cross and longitudinal sections of such a conduit. The conduit is laid on a concrete foundation, and at the joints a stoneware chair or cast-iron bearer is placed under the ends of the abutting sections, and the joint is completed with Portland cement or with a bituminous cement. To prevent the cement entering the interior of the tubes or ways, a strip of impregnated cloth may be placed round the joint as the sections are laid in position, or a special *mandrel* may be used, which can be *expanded* inside at the joints and afterwards reduced and removed.

Messrs. Doulton have made various types of earthenware duct, and their product is well known in this connection. Ducts are sometimes made with special *ball-and-socket joints*, which permit of perfect alignment, no

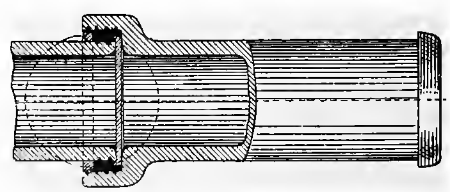


Fig. 3.—Stanford Ball-and-socket Joint

matter how the course of the line may vary. This system is a very flexible one. The Stanford joint shown in fig. 3 is representative of this class. One of Messrs. Doulton's

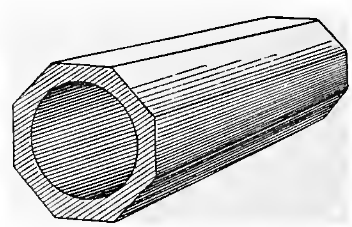


Fig. 4.—Single Octagonal Duct

types of single duct with octagonal sides is shown in fig. 4, and a section through a 16-way conduit composed of such octagonal ducts is shown in fig. 5.

In the Callender-Webber bituminous duct, the material of the duct is a mixture of bitumen, sand, and wood fibre, and the joints are made with bitumen concrete. Mandrels are used to prevent the bitumen entering at the joints. The conduit is made in about 6-ft (2 m) lengths; the length of earthenware ducts is usually about 3 ft (1 m).

Cement-lined conduit consists of wrought-iron riveted piping, lined with cement to a thickness of about 1 in (25 mm). The joints are taper, a conical end fitting into a conical recess. The pipes are laid on a bed of concrete some 8 cm thick, and have some 4 cm of the concrete between pipes and 8 cm all round. This type of conduit has been more used in America than in this country.

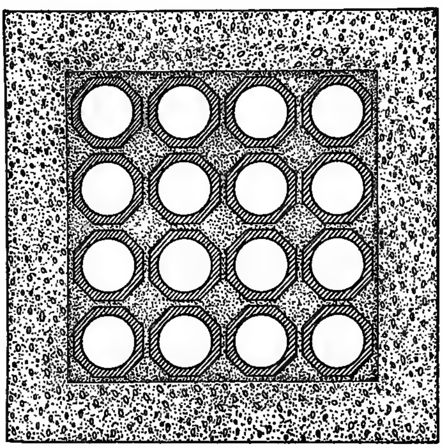


Fig. 5.—Sixteen-way Underground Conduit

VALENTINE CONDUIT.—A form of wooden conduit, consisting of planks milled with semicircular grooves in such a manner that they may be built up to form ducts. For specifications for the construction of Valentine conduit, see M'Graw's 'Standard Handbook for Electrical Engineers', §§ 270 and 271 of section 11.

Ducts of all classes are laid some 35 to 45 cm below the surface of the roadway, and draw-boxes are provided at intervals of from 50 to 100 m. Cable with a copper conductor of more than some 6 sq cm cross section cannot satisfactorily be drawn through in lengths much over 50 m, and in all cases great care must be taken to prevent injury to the lead covering of the cable. There must be no rough places or projections inside the tubes, and the ducts must be correctly in line one with another. Not more than one cable should be drawn into each duct. [F. W.]

(Ref. 'Modern Electric Practice', vol. ii; 'Electrician Primers', 2nd ed., 1906, vol. ii; 'Engineering and Electric Traction Pocket-book', Dawson.)

Conduit System.—

['*Conduit System.*—(*a*) For electric light and power distribution, a system of bare conductors carried on insulators in a conduit or culvert, generally of concrete; (*b*) for wiring, a system of metal or other pipes into which wires are drawn; (*c*) for traction, a system of bare conductors carried in a conduit, having an open slot through which a *plough* makes contact between the conductor rails and the electrical equipment of the car; (*d*) for telegraphs and telephones, a group or collection of ways or passages called *ducts*, into which cables are drawn.'—I.E.C.]

See also CONDUIT, INTERIOR; CONDUIT, UNDERGROUND; CONDUIT SYSTEM OF ELECTRIC TRACTION.

Conduit System of Electric Traction, a system in which electrical energy is supplied to the cars by means of conductors fixed in a tube or conduit beneath the surface of the road, the collector passing through a slot in the roof of the conduit. Usually both the positive and the negative conductors are insulated, and the rails do not form part of the circuit. The collector, or *plough*, carries two contact-shoes which rub against the conductor-rails to collect the current, the shank of the plough being thin enough to run in the slot without binding. The conduit may be either in the centre of the track (*centre-slot*) or under one of the rails (*side-slot*). The London County Council Tramway System is by far the largest undertaking in which the conduit system of electric traction is employed. [A. H. A.]

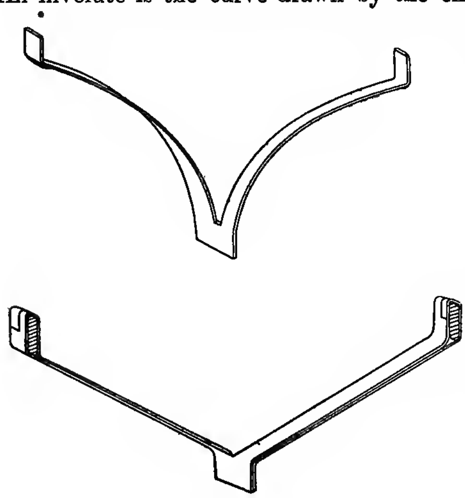
Conduit Way. See WAY.

Conkling Process of Ore Separation. See SEPARATION OF ORES.

Connections, Butterfly, the fork-shaped strips used to connect together bars at different positions on the armature. In large machines, especially where the teeth are wide, these connections may be straight, but in small cc machines they must be curved in the manner shown in the upper part of the figure, as the room available may diminish by as much as half, as the lowest point is reached, and the room occupied by the strip is the width of a horizontal section at various points. This width, in the case of the straight connections, is constant. These connections may take either of the following forms.

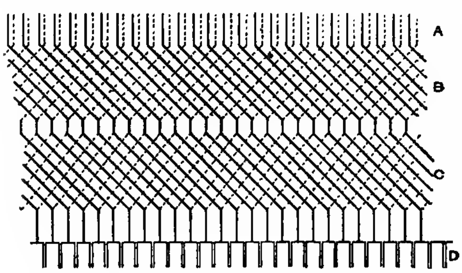
Spiral Connections. — Used in armature windings to connect one conductor to another similarly situated under the next pole. They consist of double spirals, and in cc machines the commutator is usually connected to the junction of the two spirals.

Involute or Evolute Connections.— An involute is the curve drawn by the extremity of a piece of string which is unwound from a circular drum. It should be the shape taken by the spiral connections used on some types of cc armature windings. [H. W. T.]



Butterfly Connections

Connections, Cross, are used for three purposes, viz. (1) for equalizing the currents in the various sets of brushes in multipolar dynamos (see Connections, Equipotential), (2) in order to enable one pair of brushes only to be used on a parallel-wound armature, and (3) in order to connect various coils of an armature to form a series grouping.



Butterfly Connections for a Cross-connected Winding

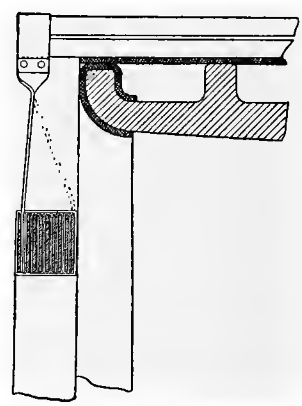
A, Armature Conductors. B, Armature Connections. C, Equalizing Connections. D, Commutator

The connections are usually effected by butterfly connections from the commutator bars in place of the usual straight lugs. The figure affords an example of a cross-connected armature. The same purpose might also be served by a system of butterfly connectors at the free end of the commutator.

With regard to heading (3) above, this system of series connections is now obsolete, and was used more especially in connection with ring-wound armatures. Those interested will find a complete historical survey in Thompson's 'Dynamo-Electric Machinery', vol. i, p. 409. [H. W. T.]

Connections, End. See End Connections; Hobart-type of End Connection; 'Eickemeyer Coil' under Coil, Form-wound.

Connections, Equipotential, electrical connections made between points in different circuits, or different parts of the same circuit, which points are, or should be, at the same potential. A more common term is *equalising connections.* The most common example is in the case of a multiple-wound continuous-current armature where *equalising rings* are fitted at the back end, and connected to equipotential points of the different sections of the winding, which are cut by the induction from different poles. Thus, by allowing alternating, equalising currents to flow between the sections, any circulation of current between the brushes on the cc side is prevented. This ensures that all the brushes shall carry equal load.

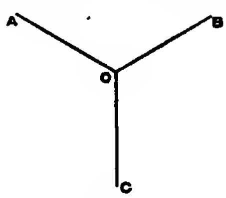


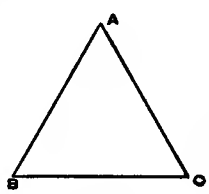
Hobart Equipotential Connections

If, for example, a six-pole multiple-circuit simplex winding has 144 turns, or 48 turns per pair of poles, then 12 equalising rings could be employed, and connections could be carried off from every fourth turn. Thus altogether 36 connections would be taken off to the equalising rings, 3 to each of the 12 rings. Other numbers of equalising rings, such as 6, 8, or even 16 or 24, could be employed in this instance; but for such a case 12 rings would accord with good practice.

As regards the mechanical construction of equalising rings, various designs have been followed. That due to Hobart and illustrated in the figure is probably the best mechanical design. Great care must be taken that only absolutely symmetrical points are connected together. The same object is also sometimes attained by means of cross connections. See CONNECTIONS, CROSS; also PUNGA EQUALISING CONNECTIONS.

Connections, Three-phase.—Two different methods may be employed for connecting up the three phases of a three-phase





Figs. 1 and 2.—Three-phase Connections

generator or motor. The three phases may be joined together at one common point, as in fig. 1, or they may be joined in the form of a triangle, as in fig. 2. The connections in fig. 1 are known as *star connections* or **Y** *connections*, and the point O, where the three phases join, is known as the *star point*.

The current in each main is obviously equal to the current in each phase winding, but the terminal emf is the vector sum of the emf in the component phase windings, that is, $\sqrt{3}$ times the emf in one phase.

The connections in fig. 2 are known as *delta connections* or *mesh connections*. In this case the emf at the terminals is equal to the emf in one phase, and it is the *current* in each line which is equal to the vector sum of the currents in two phases, *i.e.* it is equal to $\sqrt{3}$ times the current in one phase.

When lamps are connected to a three-phase system, they are divided into three equal groups, and these groups are connected to the mains either by the scheme of connections in fig. 1, which constitutes *star grouping*, or of fig. 2, which constitutes *delta grouping*.

The three phases are sometimes liable to be unequally loaded, as, for instance, in in-

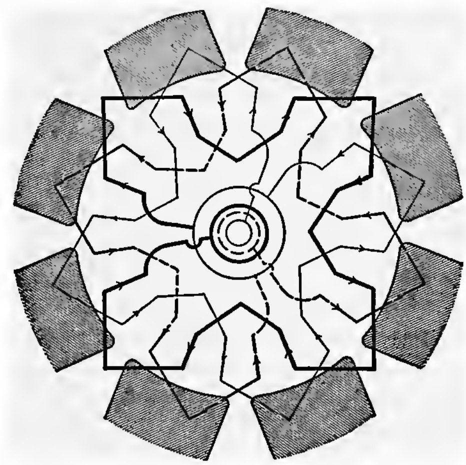


Fig. 3.—Y Connection

candescent lighting, when a greater or smaller number of lamps in each group may be in use at one time. This want of balance causes bad pressure regulation. The regulation can be improved by using *star connections* both for the generator and the lamps, and having the *star points connected by a fourth wire.* The

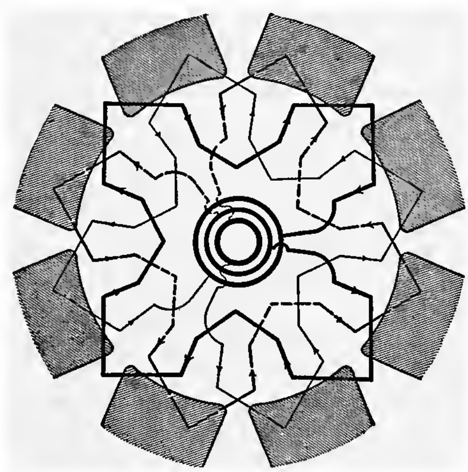


Fig. 4.—Δ Connection

section of this fourth wire may be smaller than that of the mains, depending on the amount of out-of-balance current it is intended to deal with. Such a fourth wire is rarely employed, and is unnecessary with suitable generators and a suitably designed system.

In figs. 3 and 4, a **Y**-connected winding is given at the left, and the same winding is rearranged with Δ connection at the right. [W. B. H.]

Connector, a clamping device for the connection of two or more conductors, generally for temporary use. See also END CONNECTOR.

Consequent Pole. See POLE, CONSEQUENT.

Conservation of Energy. See ENERGY.

Constantan, a copper-nickel alloy used as a resistance material. It is characterised by a remarkable constancy, and by having a temperature coefficient which is negative and too small for exact measurement. The qualities of high and constant resistance render it pre-eminently suitable for standard resistances. Its specific resistance is about 50 microhms per cm cube.

Constant Current, a current of constant value. Electricity, in quantity, is usually supplied either at constant current and at a pressure varying with the load, or at a constant pressure and at a current varying with the load. The latter system is by far the most extensively employed. See also GENERATING SYSTEMS; CENTRAL STATION FOR GENERATION OF ELECTRICITY.

Constant-current Dynamo. See GENERATOR.

Constant-current Mercury-arc Rectifier. See RECTIFIER.

Constant-current Motor. See MOTOR, CONSTANT-CURRENT.

Constant-current Transformer. See TRANSFORMER, CONSTANT-CURRENT.

Constant Induced Voltage, Method of. See SCOTT TEST.

Constant-potential Circuit. See CIRCUIT, CONSTANT-POTENTIAL.

Constant-power Generator, an electric generator which is so designed that when the current increases the pressure diminishes, thus maintaining a constant load on the prime mover. cc machines of this kind are sometimes used on petrol-electric automobiles, being driven at constant power by the petrol engine, and supplying current to motors which drive the wheels of the car. When ascending hills demanding a large torque from the motors, the current increases, while the pressure, and therefore the speed, diminishes. A somewhat similar type of machine is used for railway-train lighting, the dynamo being driven from one of the axles; but in this case the machine delivers practically constant current at constant pressure over a wide range of speed.

Constant-pressure Dynamo. See GENERATOR.

Constant-pressure Motor. See MOTOR, CONSTANT-PRESSURE.

Constant-speed Motor. See MOTOR, CONSTANT-SPEED.

Constant Terminal Voltage (or PRESSURE), the pressure across the ends of a circuit which remains at a constant value, either by reason of uniform load or by regulation. In both cc and ac circuits with fluctuating loads constant terminal pressure can be maintained by one of the following methods:—

1. A variable resistance.
2. Variation of the exciting current in the field coils of the generator.
3. Variation in the speed of the generator.

In ac circuits constant terminal pressure can also be maintained by the introduction of a variable reactance. See also CIRCUIT, CONSTANT-POTENTIAL.

Consumers' Load Factor. See LOAD FACTOR.

Consumers' Terminals. See TERMINALS, CONSUMERS'.

Contact, Electric.—When two conductors are so close together that a very small electrical pressure causes a current to flow from one to the other, they are said to be in contact.

PLATINUM CONTACTS.—Platinum may be used with advantage for contacts in which it is desired to avoid increase of contact-resistance due to oxidisation of the surfaces. The method is commonly used for press keys, for the breaks of induction coils, and for the contacts of relays.

PLATINOID OR SILVER CONTACTS.—Contacts are also made of silver or platinoid, as the heat generated by the spark on breaking contact would rapidly oxidise or melt the commoner metals.

Contact, Vibrating, an intermittent contact controlled by some timing arrangement, such as a tuning-fork; is frequently used in electrical measurements of varying quantities, such as an ac, the contact being made only during the same short portion of each wave. A vibrating contact is also used in order to allow of the growth of a current in a resonating circuit during the intervals between the periods of contact. Poulsen's ticker-receiver for wireless telegraphy is based on this principle.

Contact, Wiping, an electric contact maker in which one electrode is a spring and the other a segment of a circle. The remaining segment of the circle is usually of ebonite or other insulating material. The spring presses against the circular disk, which is made to revolve. It is used frequently in ignition apparatus for gas, oil, and petrol engines.

Contact Arm, that part of a motor starter, field rheostat, or similar device to which the moving contact or contacts are fixed. A contact arm is generally pivoted, and, in operation, the contact arm moves over fixed contacts arranged in a circle or on a portion of a circle. In some designs of starters the contact arm is arranged with the pivot in the centre, and with a contact face at each end of the arm. In these cases there are generally two sets of fixed contacts forming opposite sides of a circle. (Ref. 'Elek. Masch., Apparate, und Anlagen', Dr. F. Niethammer.)

Contact Box. See Box, Contact.

Contact Breaker, that part of a switch, circuit breaker, relay, or similar device at which the current is broken when the apparatus operates.

Contact Electricity.—When two pieces of different materials are placed in contact and afterwards separated, they are found to have acquired different potentials. If, while they are in contact, an electrical pressure be temporarily applied to them, such that, on disconnecting the source of pressure and separating the metals, the latter are at the *same* potential, it is evident that the applied pressure has balanced the natural difference of potential, and is therefore equal to it. It is generally supposed that these contact pressures, which amount for zinc and copper to over 0·8 volt, and for gold and sodium to 3·6 volts, have their origin at the contact of metal and air, and not of metal and metal. As, however, in the latter measurement the sodium was entirely enclosed in a solid insulator, it seems more likely that the difference is beween metal and metal. If the contact be made through a drop of an electrolyte, the metals are reduced to the same potential. Contact difference of potential is not the same as thermo-electric difference, as the latter appears to be the temperature-variation of the former, and the relation is thus only indirect. See Contact Series. (Ref. J. Erskine-Murray, 'Proc.Roy. Soc.', vol. lxiii, pp. 113–146, 1898.)

Contact Fault. See Fault.

Contact Maker.—For the purpose of measuring an effect at a particular time, arrangements are sometimes made to close an electric circuit for a short interval at the instant required.

A common example is the contact maker used for electric ignition on gas or petrol engines, which allows the current to flow through the coil only when the piston of the engine is at its correct position.

The method has also been employed by Joubert to determine the instantaneous pressures in an alternator. See Contact, Vibrating; Contact, Wiping.

(Ref. 'Contact Method', Joubert.)

[L. M.]

Contact Methods of Measuring Slip in Induction Motors.—There are two ways of measuring slip by this method. In the first both the generator and the motor carry a rotating contact, and these are connected in series with each other and with a battery and some detector, such as a bell, telephone, or chronograph pen. The number of contacts or breaks recorded by the detector per min gives the number of lost revolutions directly. In the event of the generator being inaccessible, the generator contact may be carried by a synchronous motor run from the supply.

In the second class of measurement only one rotating contact is used on the motor shaft, and is connected in series with a voltmeter, a lamp, or a Morse instrument across the supply terminals. Under these circumstances, the frequency or the light fluctuations determines the slip if the speed of the motor is known. [C. V. D.]

(Ref. W. H. Browne, Jun., 'Elec. World and Eng.', p. 574, Oct., 1900; G. Seibt, 'Electrotech. Zeitsch.', p. 194, Feb., 1901; B. F. Bailey, 'Elec.', p. 340, June, 1905; W. C. Clinton, 'Elec.', p. 388, June, 1905.)

Contact Potential Difference. See Contact Electricity.

Contact Rectifiers, rectifiers depending on the phenomenon that when, with certain substances, current is transmitted across a contact, its transit is less impeded in one direction than in the other. Thus contacts between carbon or silicon and certain metals have been employed as detectors in wireless telegraphy. See also RECTIFIER.

Contact Series.—When two substances are put in contact and then separated, it is found that they are, as a rule, electrified—one positively and the other negatively. Different materials may thus be arranged into a series in which each is positive to that before it and negative to that after. The series, as regards the commoner elements, and beginning with the more negative, runs as follows: Platinum, silver, gold, copper, iron, lead, zinc, aluminium, sodium. The last named is about 3·6 volts positive to gold. See CONTACT ELECTRICITY. (Ref. J. Erskine-Murray, Proc. Roy. Soc., vol. lxiii, p. 113, 1898.) [J. E-M.]

Contact Skate, a conductor carried beneath electric cars operated on the surface-contact system. The skate is usually of iron, either in one piece or in the form of a chain, and is generally magnetised by electro-magnets carried on the car, for the purpose of operating the switching mechanism in the contact studs.

Contactors, switches used on the coaches of trains operated electrically on the multiple-unit system (which see).

In the earlier multiple-unit systems each coach was provided with a separate controller, the drum of which was rotated as required, either pneumatically or by a small motor from a master controller operated by the driver at the front of the train; but as large motors were necessary, the currents to be handled were large, and there was a danger of fire owing to the fact that the various parts of the large coach-controllers were cramped together in the comparatively small space occupied by the controller. It was ultimately realised that a controller was only a collection of switches, and it was found better in every way to eliminate the controller as such, and to employ instead a number of separate switches which could be suitably protected and placed under the coaches at points where more room was available. To these switches the name *contactor* was given.

Contactors consist essentially of switch contacts operated either by a solenoid or pneumatically through a valve which is controlled by a solenoid. Where necessary, a magnetic blow-out and shields to protect the parts of the apparatus from the arc on breaking circuit are also provided. The function of a contactor is to cut in or out a step in the starting and regulating resistance, or to couple the motors in series or parallel. In modern equipments the operating solenoid generally has two windings—one to hold the contacts together, the other to give the extra pull necessary to lift the core, and so make the contact. The latter winding is under the control of a *limit* switch, or *throttle* switch as it is sometimes called, which is actuated by a solenoid carrying the motor current, and automatically limits the rate at which one contactor follows another in operation, and so in turn limits the current taken on each step. [F. W.]

(Ref. 'Electrical Traction', Wilson and Lydall.) See CONTROLLER, MASTER.

['*Contactor*, an electro-magnetic, electro-pneumatic, or automatic switch used for controlling heavy-current circuits to motors, and which is itself controlled by a master or pilot controller.'—I.E.C.]

Continuous and **Continual.**—At p. 1058 of vol. xxvi, part ii, of the Trans. A.I.E.E., Creighton prefaces a paper dealing with Protective Apparatus with certain definitions, from which the following is quoted: "*Continuous* and *Continual*, as applied to the electrical terms, retain their defined sense. A continuous oscillation is one which appears without a break. Continual oscillations are successive sets of oscillations with more or less interval between the sets. A generator furnishes continuous alternations, a Tesla transformer produces continual oscillations. Continuous lightning is sometimes produced by one phase of a generator when another phase is short-circuited. Continual lightning is produced on a non-grounded neutral system when one phase is connected to ground through an arc. Both continuous and continual lightning may be temporary, but should be distinguished from transitory lightning."

Continuous Current (preferable abbreviation cc).—A continuous current is a current flowing in one direction only.

The above is the preferable and also the most widely adopted definition of *continuous current*, and is in accordance with the decision of the I.E.C., who report as follows:—

'*Continuous current*, an electric current in one direction and sensibly steady or free from pulsation. Abbreviated cc. The term *direct current* is not recommended.'

Unfortunately, in the 1907 Standardising

Rules of the A.I.E.E., the term *direct current* is adopted for expressing the above meaning, thus:

'A direct current is a unidirectional current';

and this definition is followed by:

'A continuous current is a steady or non-pulsating direct current'.

Continuous-current Armature. See ARMATURE.

Continuous-current Armature Windings. See WINDING, CC ARMATURE.

Continuous-current Compensator. See COMPENSATOR.

Continuous-current Constant-current System. See GENERATING SYSTEMS.

Continuous-current Constant-potential System. See GENERATING SYSTEMS.

Continuous-current Converter. See CONVERTER.

Continuous-current Dynamo. See DYNAMO-ELECTRIC MACHINE; GENERATOR.

Continuous-current Electricity. See ELECTRICITY, CONTINUOUS.

Continuous-current Energy Motor-meter. See METER, CC ENERGY MOTOR-.

Continuous-current Generator, a dynamo-electric machine for the production of cc, commonly called a *dynamo.* See DYNAMO; DYNAMO-ELECTRIC MACHINE; GENERATOR.

Continuous-current Generator Characteristics.—In cc generators the term *characteristic* is often applied to the curve giving the relation of the external pd of the machine, or the emf in its armature, to the current taken from the machine when run at constant speed. Such curves were first made by Dr. John Hopkinson, in 1879, and described before the Institution of Mechanical Engineers. In such tests, the generator to be tested is run at a constant speed, and the current taken from it is varied, the current being measured by an ammeter and the pd by a voltmeter connected to the terminals of the machine. A curve is then plotted with the values of the current in amperes as horizontal distances, and of the corresponding pd in volts as ordinates, and this curve is known as the external or pd characteristic. The pd at the terminals of the machine is, however, less than the emf generated in its armature, owing to the drop of potential due to the resistances of the armature and brush contacts, and of any series coils connected between the armature and the terminals. This drop can be calculated from a knowledge of the current and of the resistance of the armature, and of such contacts or coils. By adding this drop of potential to the external pd, the emf generated in the armature is obtained, and a curve plotted with these values of the emf instead of the internal pd is what is termed the "internal" or "emf" characteristic of the generator. See CURVE, CHARACTERISTIC.
[C. V. D.]

Continuous-current High-tension System. See SERIES DISTRIBUTION.

Continuous-current Motor. See MOTOR, CONTINUOUS-CURRENT.

Continuous-current Switchboard Integrating Meter. See METER, SWITCHBOARD INTEGRATING.

Continuous-current Three-wire Meter. See METER, THREE-WIRE.

Continuous-current Watt-hour Meter. See METER, CC WATT-HOUR.

Continuous-current Watt-hour Motor-meter. See METER, CC WATT-HOUR MOTOR-.

Continuous Electricity. See ELECTRICITY, CONTINUOUS.

Continuous Oscillations.—When a periodic movement is uniformly repeated in successive equal intervals of time, the result is a continuous oscillation. The movement may be electrical, mechanical, or otherwise.
[J. E-M.]

Continuous Rail Joint, a type of joint in which, as seen in fig. 1, the fishplates are shaped to fit round and to partially enclose the flanges of the rails to be joined, so as to hold them rigidly in alignment. If only a thoroughly reliable system of continuous rail joints could be developed, it should be of great value in electric traction, as there would be the additional advantages consequent upon greater electrical conductivity of the rail. Many patterns have been devised, differing in detail.

Fig. 1.—Continuous Rail Joint

The *Romopac Rail* is a type of continuous rail joint. It is a compound rail consisting of a lower permanent tee-rail, on the head of which a renewable upper channel-rail is laid, the flanges of the channel being rolled and crimped so as to grip tightly the head of the lower rail by means of a special travelling machine. When worn, the upper rail can be detached and a new one substituted at a less cost than that of renewing the whole of the track rail. (Ref. 'Elec. Rev.', Feb. 16, 1906, p. 245.)

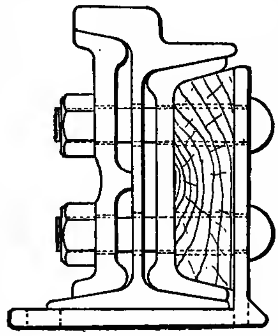


Fig. 2.—Weber Type of Continuous Rail Joint

The *Weber Rail Joint* is illustrated in fig. 2. It is characterised by having an L-shaped member, the horizontal portion of which extends under the rails. It has also the two customary channel joints and bolts running through these three members and the web of the rail. See also BOND; WELDED RAIL JOINT; RENEWABLE PLATE FOR RAIL JOINTS.

Continuous Rating. See RATING, CONTINUOUS.

Contract Demand System, a system of charging electricity consumers which was proposed in 1908 by Handcock and Dykes in a paper read before the I.E.E. Messrs. Handcock and Dykes explain the system as follows:—

'A consumer applying for a service states the number and cp of lamps he proposes to use—say, for example, 200 8-cp lamps. From his knowledge of the district the station manager estimates that the maximum demand he is ever likely to make on the station is, say, 3 kw, which he accordingly enters as his *contract demand*.

'For the privilege of having the call at any time on power up to 3 kw, the consumer will pay per annum a fixed sum, and in addition a small charge per unit for the actual energy supplied as measured on the ordinary meter. The fixed charge represents the cost the station is put to in placing at his disposal a supply up to 3 kw, and is independent of whether he actually uses a unit or not. It is arrived at by dividing the sum representing the whole of the *preparation costs*, that is, all those which are independent of the actual output of the station, including, in the case of companies, a reasonable dividend, by the sum of the consumers' *contract demands*. The charge per unit is intended to represent the *production cost* per unit consumed, with a reasonable margin of profit.'

See INDICATOR, MAXIMUM DEMAND; CURRENT LIMITER.

Contrast Photometer or Contrast Photometer Head. See PHOTOMETER HEAD, CONTRAST.

Control, Cascade. See CASCADE MOTOR.

Control, Closed-circuit. See CONTROL, OPEN-CIRCUIT.

Control, Electric, of Pneumatic Apparatus.—This is a method of controlling pneumatic apparatus by electromagnets or electric motors, and is consequently just the reverse of controlling electrical apparatus by means of compressed air. See also CONTROL, PNEUMATIC, OF ELECTRIC APPARATUS.

Control, Electromagnetic, the control of apparatus by means of electromagnets, as, for instance, of oil switches (see SWITCH, OIL-BREAK), and of contactors on multiple-unit traction equipments (see CONTACTORS). There are indeed, numberless applications of electromagnetic control, largely because it lends itself so readily to control from a distance. Sometimes the term is rather loosely used to cover control by means of small auxiliary electric motors. [F. W.]

Control, Instrument. See INSTRUMENT CONTROL.

Control, Open-circuit.—Controllers are often so arranged that in varying the circuit combinations in going from point to point the circuits are interrupted at the instant of departing from the one point, and are closed again in the new combination when coming to the next point. This may be termed *open-circuit control*.

The alternative method is to recombine the circuits in the desired way without interrupting them. This is termed *closed-circuit control*.

Thus, in British patent No. 1374 of 1904, it is set forth that a 'reduction of the sparking results from not completely breaking the field circuit, and therefore not rendering the motors electrically inactive, but, on the contrary, leaving the motor armatures in circuit, and with a magnetic field of considerable intensity for them to revolve in, thereby making this part of the motor-control conform with the principle of what is known as *closed-circuit control*.

Control, Pneumatic, of Electric Apparatus, the actuating of electric apparatus, chiefly switch gear, by means of air pressure. Compressed air is employed in the operation of the contactors in some multiple-unit traction systems (see also CONTACTORS and SWITCH, ELECTRO-PNEUMATICALLY CONTROLLED UNIT-), and also in connection with switch gear for automatically starting or controlling the speed of motors that drive air compressors. In the latter case the switch gear may be connected to a piston (either directly or through a relay) which is pushed farther into a cylinder as the air pressure rises, and returns as the pressure falls. Compressed air is also sometimes used in the operation of large oil switches, and to raise and lower the trolley collectors on electric railways (working on the overhead system). Compressed air is, of course, largely used to operate brakes on electric railways, haulage gears, &c., and in these cases is often controlled electrically by means of electromagnets, but this is rather the electric control of pneumatic apparatus. (Ref. 'Electrical Traction', Wilson and Lydall.) [F. W.]

Control, Regenerative. See Regenerative Control Systems; Crane, Electric.

Control, Remote. See Remote Control System.

Control, Rheostatic.—In the early days of electric traction the speed of the series-wound motors on the car was often regulated by varying a resistance in series with the motor or motors. This was termed *rheostatic control*, and was at a later stage superseded by series-parallel control. Of course in various applications of electric motors the control is effected wholly or partly by rheostatic adjustments. See also Control, Series-parallel; Controller.

Control, Series-parallel, a system in which two or more electric motors are connected in series when starting or running at low speed, and in parallel when running at high speed, in order to secure ease of regulation and economy in working. The whole of the changes of connections are effected in their proper order by the rotation of a drum or cylinder provided with suitable contact devices (the *series-parallel controller*). A supplementary drum provides for the reversal of the direction of rotation of the motors when required. Similar controllers are used for railway locomotives and motor cars, for some types of electromobile, and for other purposes. See also Control, Rheostatic; Controller. [A. H. A.]

Control Cable Couplers. See Jumper.

Controller, an apparatus for performing a number of switching operations, generally equivalent to a multi-contact switch or a combination of switches.

A controller most often consists of an insulating drum or cylinder, with a number of segmental contacts, which is rotated by a handle and makes contact, in the desired order, with a corresponding number of fixed contacts, which generally take the form of fingers, pressed against the cylinder by springs, the whole being enclosed by a suitable cover. Leads are taken out from the contacts to the motors, resistances, &c.

Controllers are generally used for starting, stopping, reversing, and controlling the speed of electric motors, where one or more of these operations have to be frequently repeated. They are in practically universal use on electric tramcars and electric rolling stock in general. For traction purposes it is, as a rule, necessary to couple motors both in series and in parallel, and the controllers are designed to make the necessary changes of connections. Further, it is often required that the motors shall act as generators for braking purposes, and to this end brake contacts are added to the controllers. In traction controllers, therefore, the number of contacts becomes considerable, and the reversing is frequently effected by a subsidiary cylinder operated by a second handle, but interlocked with the first cylinder in such a way that it is impossible to reverse unless the main cylinder is in the 'off' position. Traction controllers, and other controllers dealing with large currents and with pressures of 500 volts or so, are often provided with a *magnetic blow-out controller*, an electromagnet having a pole face of suitable shape to provide a series of magnet blowouts at the points where the contacts break circuit, and a *click device* is generally provided to ensure that the cylinder is not left in an intermediate position between two contacts.

Controllers are almost infinite in their variety, and are in general use in place of motor-starting switches, not only in traction equipments, but also in connection with electric cranes, winches, haulage gears, and other motor drives where switching operations have to be very frequently effected. They are generally of stronger construction than ordinary motor-starters, and parts subject to wear can be easily and cheaply renewed. Controllers are made for both cc and ac circuits. See also Control, Series-parallel; Control, Rheostatic.

Many special forms of controller are in use, as, for instance, automatic lift controllers, referred to under Switch, Auto-

MATIC, and LIFT, ELECTRIC. See also CONTROLLER, MASTER.

(Ref. 'Electrical Traction', Wilson and Lydall; 'Elec. Masch., Apparate, und Anlagen', Dr. F. Niethammer.) [F. W.]

['*Controller*, a compound or multiple switch containing the means for introducing resistances, or for connecting motors in series or in parallel. It has several steps or positions called *notches*, and is intended for use on any notch for an appreciable period of time. It is to be distinguished, in this respect, from a *starting switch*. It is used for varying the speed or power of, as well as for starting, traction and other motors. A *master controller*, sometimes called a *pilot* or *multiple-unit controller*, does not act directly on the current supplied to the motors, but works *contactors*.'—I.E.C.]

Controller, Automatic Lift. See LIFT, ELECTRIC.

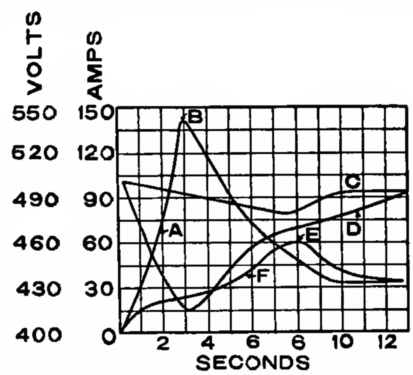
Controller, Master, a controller that brings other controllers or switches into operation. Such controllers are used chiefly in connection with multiple-unit systems of train control. In such systems, where the individual switches, or contactors, on the coaches are electrically operated, the master controller generally takes its current from the line at, say, 500 or 600 volts, and hence, although the currents that the master controller deals with are comparatively small, a magnetic blow-out and arc shields are provided. A master controller generally has a single handle actuating a barrel with comparatively small contacts, and the currents that it controls pass through small conductors running along the train, and bring into operation the contactors on each coach that place the motors in series or parallel, and insert or cut out resistance as required. They also operate a separate reversing switch on each coach.

Where an electro-pneumatic system of control is used, the currents from the master controller only operate valves on the contactors that admit or release the compressed air that actuates the switch mechanism. Consequently still smaller currents suffice, with the result that a few secondary cells are often used to supply the master-control circuits, and the master controller itself need not be fitted with arc shields or magnetic blow-out.

A master controller is provided at each end of the train to enable the driver to be always at the front, and the two controllers are connected to the same train-wires. All master controllers generally have what is called a *dead man's handle*; that is to say, the handle is provided with a button or similar device so arranged that, should the driver relax his grasp, current would be cut off from the train and the brakes would be automatically applied. See also MULTIPLE-UNIT SYSTEM OF TRAIN CONTROL; CONTACTORS.

(Ref. 'Electrical Traction', Wilson and Lydall.) [F. W.]

Controller-regulator for Electric Cars, a device applied to the controller



Curves showing desirability of employing Controller-regulator for Electric Cars

A, Amps wrong start. B, 79·7 H.P. Max. C, Volts correct start. D, Volts wrong start. E, 38·6 H.P. Max. F, Amps correct start.

rendering it necessary for the driver to remain for a suitable length of time on each controller point. This tends to prevent slipping of wheels, and also smooths down the peaks in the load curve. It would, however, appear questionable whether it is so universally efficacious in saving energy as its advocates are accustomed to assert. The curves in the above figure have been put forward by the exploiters of a device of this type. See also REGULATOR, CONTROLLER.

Controllers for Electric Cranes. See CRANE, ELECTRIC.

Convection, Electric, the transference of electric charges by the movement of material bodies on which they are situated, *e.g.* on particles of water in a thunder cloud or particles of dust in an insulating liquid, also by the motion of charged molecules in a gas. [J. E-M.]

Convection, Electrolytic. See ELECTROLYSIS.

Convective Discharge. See DISCHARGE, CONVECTIVE.

Conversion, Efficiency of. See EFFICIENCY.

Converter, a term whose general meaning is synonymous with that of *transformer* (which see), but which is generally used to denote the rotating type of transformer. See ROTARY CONVERTER. [R. C.]

['*Converter*, a revolving apparatus for converting ac into cc, or vice versa; sometimes called a *rotary converter*. To be distinguished from a *transformer*, *rectifier*, or *motor generator*.'—I.E.C.]

According to paragraphs 16 to 21 of the 1907 Standardisation Rules of the A.I.E.E.:

'A *converter* is a machine employing mechanical rotation in changing electrical energy from one form into another. A converter may belong to either of several types, as follows:—

'(*a*) A *direct-current converter* converts from a direct current to a direct current.

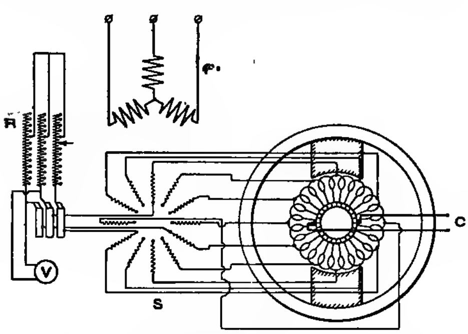
'(*b*) A *synchronous converter* (commonly called a *rotary converter*) converts from an alternating to a direct current, or vice versa.

'(*c*) A *motor converter* is a combination of an induction motor with a synchronous converter, the secondary of the former feeding the armature of the latter with current at some frequency other than the impressed frequency; *i.e.* it is a synchronous converter concatenated with an induction motor.

'(*d*) A *frequency converter* converts from an ac system of one frequency to an ac system of another frequency, with or without a change in the number of phases or in voltages.

'(*e*) A *rotary phase-converter* converts from an ac system of one or more phases to an ac system of a different number of phases, but of the same frequency.'

Converter, Cascade (often termed *motor converter*), a machine invented by La Cour,



Cascade Converter

V, Synchronising Voltmeter. S, Secondary Winding. P, Primary. C, Continuous-current Terminals. R, Starting Resistance.

and used for converting alternating to continuous current. It consists of an induction motor coupled directly to a rotary converter. The stator of the motor is connected to the supply mains; the rotor is provided with a polyphase winding, and this is connected at appropriate points with the armature winding of the rotary converter, which gives out cc at the commutator. The rotor of the motor under these conditions runs at half the speed corresponding to synchronism, and half the power supplied to it is converted into mechanical power, which is transmitted through the shaft to the rotary converter and drives the latter as a generator, the other half of the power being transmitted electrically to the armature of the rotary converter and converted to cc. See MOTOR, INDUCTION; ROTARY CONVERTER; CASCADE MOTOR. (Ref. 'Elec. World', vol. xlvi, pp. 230–231.)

A diagram of connections for a cascade converter is given in the figure. A two-pole converter is shown, simply for the greater convenience of diagrammatical explanation. In this case the rotor of the induction-motor element is wound with twelve phases, while the stator is wound three-phase. R is an ordinary starting rheostat, such as is employed with ordinary induction motors. V is a synchronising voltmeter. P is the primary and S the secondary of the induction motor component of the cascade converter. See also CONVERTER.

Converter, La Cour. See CONVERTER, CASCADE.

Converter, Motor. See CONVERTER, CASCADE.

Converter, Rotary. See ROTARY CONVERTER.

Convertible Energy of Steam. See ENERGY, CONVERTIBLE, OF STEAM.

Conveyor, Electric Underground. See UNDERGROUND CONVEYOR, ELECTRIC.

Conveyor for Coal in Electricity Supply Stations. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Cooking by Electricity.—Apparatus for cooking by electricity depends for its action upon the heating effect of the current. The apparatus is usually provided with resistance coils so proportioned that when traversed by the proper amount of current they occasion the required temperature rise.

Cooling Surface, the surface through which the heat generated or contained in any body passes out of the body. In dynamo design certain surfaces are usually more or less arbitrarily chosen, from which it is assumed that the whole heat generated is emitted. The figures so obtained, though of no *absolute* value, are useful in comparing different machines of the same type.

The arbitrary method is rendered necessary because the efficiency of different surfaces in getting rid of heat waves varies with the nature of the surface and with the amount of air circulated over it, either automatically or through the centrifugal or the fanning action of the rotating parts. It is thus practically impossible to determine accurately what amount of heat passes out through any given portion of the surface, and only average values can be dealt with.

The total losses, expressed in w, divided by the cooling surface in sq dm, give as quotient the w per sq dm. This figure is a measure of the final temperature-rise above the temperature of the surrounding air. Thus *armature cooling-surface* is frequently taken as being the cylindrical surface of the armature, $\pi d l$, where d is the diameter and l the length parallel to the shaft. l is sometimes measured over the end windings, or it may be taken as the length of core only. In the first case 1 w per sq dm will give a rise of from 0·7°, if the peripheral speed is some 20 m per sec, up to 1·5° C., if the peripheral speed is only some 8 m per sec. If l be measured over the core only, these figures become about 0·4° and 1·0° C. respectively. These results apply to modern cc dynamos and motors of the open type only. Higher values hold for enclosed machines. The cooling surface of stationary magnet coils within which an armature rotates is usually taken as the cylindrical surface, for coils which are long compared to their depth; for deep coils one end of the winding is usually added to this, and reckoned as cooling surface. Cooling surfaces so calculated will emit from 8 to 15 w per sq dm at a temperature rise of 40° C., according to the amount of ventilation. In totally enclosed motors and in static transformers the w per sq dm are usually reckoned over the whole external surface of the case. [W. B. H.]

Cooling Tower. See TOWER, COOLING.

Cooper-Hewitt Lamp. See LAMP, TUBULAR.

Cooper-Hewitt Mercury Vapour Rectifier. See RECTIFIER.

Copal.—This term has come to be applied to a class of resins used for varnish manufacture. It was originally the name given to a fossil resin found on the west coast of Africa. [H. D. S.]

Copal Varnish, a varnish containing one or more copal resins. It may be either an oil or spirit varnish, but the term is more frequently applied to the former. [H. D. S.]

Co-phasal, a term sometimes used to denote the coincidence in phase of two ac quantities. See also PHASE.

Copper (symbol = Cu). In electrical engineering the material at present most widely employed as a conductor is copper. In point of conductivity by volume, copper stands second to silver, the use of which is usually out of the question by reason of its cost. The toughness, ductility, and flexibility of copper make it easy to work into convenient forms, and it is very suitable for the winding of machines and transformers. It is non-magnetic. A large number of useful alloys contain copper as a constituent.

The physical properties of pure annealed copper are as follows:—

Specific gravity	8·9
Coeff. of linear expansion	0·000017 per deg. C.
Resistivity at 0° C.	15·9 microhms per cm cube.
Coeff. of increase of resistance for 1° C.	0·004
Specific heat	0·095
Melting-point	1050° C.

Annealed copper is characterised by extreme ductility and flexibility, combined with a very low elastic limit. It is in this form that the metal is generally used for windings.

Hard copper is produced when copper is stressed much beyond its elastic limit, whether by tension, by hammering, or by bending. At the same time the resistance and density are slightly increased. Hard copper is used for commutator segments, and occasionally for end-windings of electric machines where stiffness is a desideratum.

Hard-drawn copper wire has an elastic limit of about 28 kg per sq mm, and a modulus of elasticity of about 11,300 kg per sq mm.

As a conductor, copper has a rival in aluminium, and may find another in sodium. Iron and steel are also widely employed as conductors; for instance, for the conductor rail of electric railways. The track rails are also often employed for the return current. See ALUMINIUM; SODIUM; ELECTROMETALLURGY; WIRE, COPPER; HARD-DRAWN COPPER WIRE. [J. S. S. C.]

Copper, Weight of, in Transmission Systems. See ALTERNATING-CURRENT SYSTEM.

Copper Bath. See ELECTROMETALLURGY.

Copper Brushes. See BRUSHES.

Copper Conductivity Standard. See RESISTANCE, MATTHIESEN'S STANDARD OF.

Copper Efficiency. See EFFICIENCY, COPPER.

Copper Factor, the ratio of the cross section of a conductor to the area of the space actually occupied by that conductor when insulated and forming part of a winding. See also SPACE FACTOR.

Copper Loss. See LOSS, COPPER.

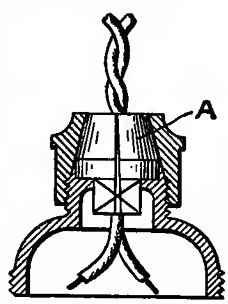
Copper Sheathing of Cables. See CABLE, UNDERGROUND.

Copper Sulphate, Electrolysis of. See ELECTROLYSIS.

Copper Voltameter. See VOLTAMETER.

Copper Wire. See WIRE, COPPER.

Cord-grips are used in cases where fittings are supported by flex (such as for pendants), in order to relieve the electrical connection between the flexible conductor and the fitting, of any stress. The figure shows one form of cord-grip for an ordinary pendant lamp holder. In this form the wood grips are clamped to the flex, by screwing down the cap. There are other forms of cord-grips, but the above are most used.



Cord-grip
A, Wood Grips.

Core.—

['*Core*: (*a*) Of a magnetic circuit. That part which is within the winding. The part outside the winding, if any, is called the *yoke*. (*b*) Of a transformer. The whole of the iron forming the magnetic circuit. (*c*) Of a cable. The conductor, with its insulation or dielectric. Two, three, or more cores may be laid together to form a *twin*, *three-core*, or *multicore* cable. (*d*) Of an arc-lamp carbon. The longitudinal filling.'—I.E.C.]

Core, Armature, the body of an armature which is built up of iron laminations and which carries the flux from pole to pole. At its surface, it is provided with longitudinal slots, in which the armature conductors are placed.

Core, Cable, the conductor portion of a cable, as opposed to the insulation or to the protective portion. See CORE; CABLE, UNDERGROUND.

Core, Laminated. See LAMINATED; CORE, ARMATURE; ARMATURE; CORE DISKS; LOSS, CORE.

Core Disks (often termed *Core Plates* or *Laminations*), the sheet-steel stampings of which the body of an armature, *i.e.* the *armature core*, is built. They vary in thickness in different machines between 14 and 40 mils (0·36 mm and 1 mm), the most usual size being 20 mils (0·5 mm). The necessity for this fine lamination lies in the fact that eddy currents are produced in the rotating iron of the armature, and the finer the laminations the greater is the reduction in the eddy-current losses. The core plates are stamped with notches in the rim, and when the several plates are assembled these notches constitute slots, in which the armature conductors are placed.

SEGMENTAL CORE DISKS.—In armatures of large size the core ring is built up of several

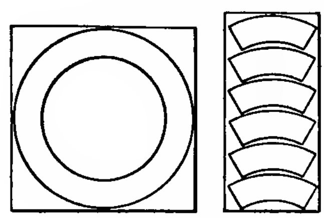


Fig. 1.—Segmental Core Disk

separate stampings. This is to avoid the excessive cost of a single die and the great waste of material when a complete ring is stamped. This will be seen from fig. 1, in which the waste is less with the segmental punchings than with the complete punchings, even after allowing credit for the blank centre. Furthermore, when over 1 m wide, the cost of sheet iron or steel is very high, and at still greater widths it is not a commercial article. Each segment is often provided with two dovetails or lugs, so situated that, in assembling, the consecutive layers of punchings may be staggered with regard to one another.

PIERCED CORE DISKS.—A method of assembling core disks, less used now than formerly, was to thread them upon bolts which ran from side to side of the machine. For this purpose the core disks, in the process of stamping, were provided with at least two holes per segment, near the inner or outer periphery, according as the winding was upon an external stator or upon a rotor, in order to allow the segments in the various layers to be staggered. The through-bolts were usually insulated with wrappings of paper or by other means, in order to prevent the formation of conducting circuits.

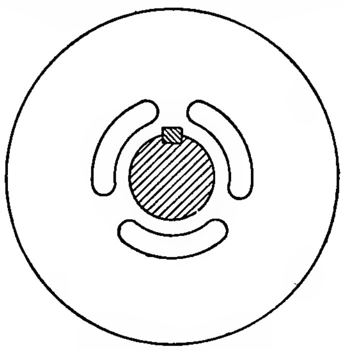
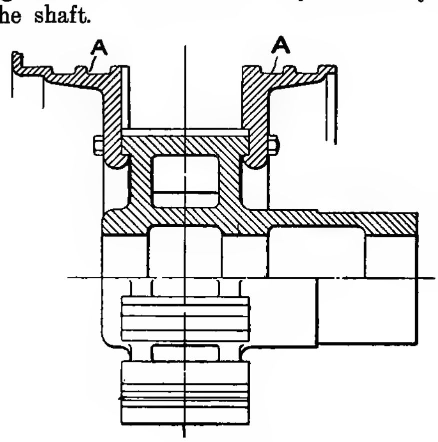


Fig. 2.—Pierced Core Disk

The expression *pierced core disks* is also used when armature core disks of small size are threaded directly on the shaft and are provided with apertures, as indicated in fig. 2, for the admission of air to cool the core.

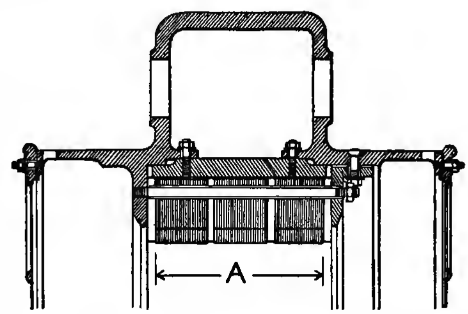
Keyed Core Disks.—A common method of securely assembling core disks on a spider or in a frame is by means of keys. The frame is slotted to receive the key, and the core disks, in stamping, are provided with corresponding slots. In the illustration in fig. 2 the core disks are keyed directly to the shaft.



Core Heads

Core Heads, the castings placed at the ends of laminated cores to afford lateral mechanical support. They are often provided with fingers, so as to support the laminations in the region of the teeth, and are preferably ribbed on the inside. This, besides affording a more reliable means of pressing up a core than a flat surface, allows a free circulation of air through the core. The core heads are secured either by bolts running from end to end of the core, by circumferential keys, or by bolts holding them directly to the frame. In the figure the core heads A A are secured by bolts.

Core Length, length across the laminations of the iron core of an armature, transformer, or other apparatus.



Core Length

Gross Core Length (preferably denoted by λ_g) is measured over-all from end lamina to end lamina, that is, between core heads. In the illustration the gross core length is shown at A.

Nett Core Length (λ_n) is the part of the gross length actually occupied by iron, and is obtained from the gross core length by deducting the space occupied by ventilating ducts and by the insulation between laminæ.

Core Loss. See Loss, Core.

Core-loss Current, that component of the current in a transformer or alternating motor which supplies the eddy current and hysteresis losses in the iron core.

The no-load current (often called the *magnetising current*) of a transformer or alternating motor is made up of two components: (1) the magnetising current proper, which is in quadrature with the applied pressure; and (2) the core-loss current, which is in phase with the applied pressure, and supplies the watts lost in eddy currents and hysteresis in the iron core or cores.

Core-loss Curve. See Curve, Characteristic.

Core Plates. See Core Disks; Core, Armature.

Core-plate Varnishes, quick-drying varnishes employed for the insulation of punchings. They should give a hard, tough coat that will not soften with heat or become brittle and powder under vibration. Core-plate varnishes may be applied either by dipping the punchings, or by passing them through a japanning machine. They are used at a very thin consistency, and the solvent employed should be a very volatile spirit.

Core-plate varnishes may be divided into two classes. viz.:—

1. Quick-baking Varnishes.
2. Quick Air-drying Varnishes.

QUICK-BAKING VARNISHES.—These are baking varnishes that dry in a few minutes at a temperature of 85° to 95° C., and are employed for the insulation of punchings for oil-cooled apparatus. In addition to the properties already enumerated, they should be insoluble in hot oil.

QUICK AIR-DRYING VARNISHES.—These are varnishes that air-dry in a few minutes, and may be employed on any punchings that are not to be used in oil-cooled apparatus.

Core Reluctance, the reluctance of that part of the magnetic circuit which lies in the core. See RELUCTANCE.

In calculating the reluctance of the laminated core of an armature, the mean length of path is best measured from a scale drawing of the machine, on which the approximate mean path of the magnetic lines has been sketched in. The mean section of path is calculated, making allowance for the insulation between the disks of which the core is built, and for any ventilation ducts that may be present.

For the solid cores of a magnet the mean length and section of path are simply the length and section of the iron.

Cored Carbons. See CARBONS, ARC LAMP.

Coreless Armature. See ARMATURE.

Corkscrew Rule, a rule (which appeals to many) for remembering the relation between the direction of a current and the direction of the magnetic field produced by the current. This relation is the same as that between the twist and thrust of a corkscrew. Looking at a circuit in which the current is flowing clockwise, or right-handedly, the direction of the resulting field is from the observer towards the circuit. This means that the polarity induced in a pole by a clockwise current round it is S, and the direction of the lines of force in the pole is from S to N. See CURRENT, DIRECTION OF; FLEMING'S RULE; AMPERE'S RULE.

Corrosion, Electrolytic.—The passage of current through damp earth, or through *any* damp material, will cause corrosion at the metal surface at which it enters, this metal surface corresponding to the anode in an electrolytic bath. Electrolytic corrosion is also liable to occur if a joint between two conductors of different metals, say copper and aluminium, is not protected from access of moisture. See ELECTROLYSIS.

Corrugation of Rails. See RAIL CORRUGATION.

Corsepius Single-phase Motor. See SINGLE-PHASE MOTOR, CORSEPIUS.

Cos ϕ. See POWER FACTOR.

Cosine Law. See LAW, COSINE.

Cotton as an Insulator.—The use of cotton for the insulation of magnet-wire is here considered. Cotton has no great insulating properties, but serves chiefly to separate turns between which there is a low potential difference. For this purpose it provides a good covering, and is much cheaper than silk. But the finest cotton spun-yarn will not give such a thin covering as silk. The rapid deterioration of cotton with heat has led to the introduction of the many impregnating and heat-dissipating materials at present on the market. Impregnating the cotton covering of wire enables it to withstand a higher temperature without deterioration, and is now quite common practice. See also SILK AS AN INSULATOR; BERRITE; ELECTRO-ENAMEL.

Cotton-covered Wire. See WIRE, COTTON-COVERED.

Coulomb, (1) a distinguished French natural philosopher who investigated the laws of electrostatic attraction and repulsion; (2) the practical unit used in the measurement of quantities of electricity, being the quantity of electricity transferred by a current of 1 amp in 1 sec. One-tenth of a cgs unit in the electromagnetic system. Also called the *International Coulomb*. See AMPERE. [F. W. C.]

[' *Coulomb*, the practical unit of electrical quantity. 1 coulomb is equivalent to 1 amp flowing for 1 sec; 3600 coulombs = 1 amp hr. The term *ampere hour* is almost universally adopted; the *coulomb* is seldom used.'—I.E.C.]

Coulomb Meter. See METER, QUANTITY; 'Ballistic Galvanometer' under GALVANOMETER; GRASSÔT FLUXMETER.

Coulomb's Law. See LAW, COULOMB.

Coulomb's Torsion Balance. See TORSION BALANCE, COULOMB.

Counter, Electric, an instrument for counting the revolutions of a shaft or other revolving body by making contact in an electric circuit once per revolution of the shaft.

Counter Electromotive Force. See ELECTROMOTIVE FORCE, COUNTER.

Counter Electromotive Force Cell. See CELL, COUNTER EMF.

Counter Electromotive Force of the Arc. See ARC.

Counter Pressure, a term sometimes used to indicate counter emf. See ELECTROMOTIVE FORCE, COUNTER.

Counting Train. See INTEGRATING MECHANISM; DIAL REGISTER.

Coupler, a device, generally of the plug-and-socket type, for connecting or disconnecting two portions of an electric circuit. Couplers are in general use in multiple-unit traction systems, to connect together the control circuits of the various vehicles composing a train. See also COUPLER, BUS-LINE. (Ref. under 'Multiple-unit System'; 'Electrical Engineer's Pocket Book', Foster.)

Coupler, Bus-line, a device by means of which the conductors connecting the master controllers on an electric train with one another and with the controlling switch-gear are coupled up between the cars in the proper order, without possibility of error. See JUMPER RECEPTACLE, BUS-LINE.

Coupler Plug. See JUMPER.

Coupler Socket. See JUMPER.

Coupling.—When two circuits, carrying ac (usually of hf), influence one another by mutual induction, or through having a short portion of their conductors in common, they are said to be *coupled.* The coupling is said to be *strong* if their mutual induction is a large fraction of the total induction in either, and *weak* or *loose* if it is a small fraction. The terms *close* or *direct coupling* indicate that a portion of the conducting circuit is common to both. For sharp tuning, *i.e.* when it is required that the secondary circuit should only be affected by a small range of frequencies, it is necessary to use a loose coupling. As an instance of this, it may be mentioned that signals have been received over several hundred miles by Poulsen apparatus when the helices forming the primary and secondary of the receiving transformer were separated by as much as 3 ft., their diameters being only about 10 in., there being about 30 turns of wire on each helix. See also COUPLING, CONDUCTIVE; COUPLING, ELECTRIC; COUPLING, INDUCTIVE. [J. E-M.]

Coupling, Cable, an arrangement for clamping together two conductors, usually consisting of two thimbles which lock in one another, and which are provided with an insulating sleeve with end pieces which screw

Cable Coupling

along the sleeve and up against the shoulders of the thimbles (see fig.).

Coupling, Conductive, where two circuits are coupled by having a short portion in common. See COUPLING; COUPLING, ELECTRIC; COUPLING, INDUCTIVE.

Coupling, Electric, or inductive-electric, where two circuits are coupled by means of condensers. (The term is used in Wireless Telegraphy.) See also COUPLING; COUPLING, CONDUCTIVE.

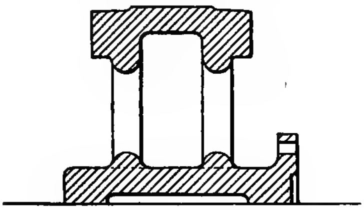
Coupling, Flexible, a coupling in which the ends of the two shafts are connected to one another through joints which allow of a slight lateral movement of the two shafts with regard to one another. This method of coupling is widely employed on turbo-generators, between the turbine and the electric generator, as in this way each shaft may have its own two bearings and may take up a simple shape when loaded with its own weight. By this means vibrations and balancing troubles are reduced. See COUPLING, SHAFT; OLDHAM'S COUPLING; PLATE COUPLING.

Coupling, Inductive, the connection of two circuits by mutual (magnetic) induction. Usually a coil or helix forms part of each circuit, and these coils are brought near to one another. (The term is used in Wireless Telegraphy.) See also COUPLING; COUPLING, CONDUCTIVE; COUPLING, ELECTRIC.

Coupling, Insulating. See INSULATING COUPLING.

Coupling, Plate. See PLATE COUPLING.

Coupling, Shaft, the means whereby two separate pieces of machinery are connected together so that they may rotate as one piece. The usual machine coupling consists of flanged bushes, which are keyed to their two respective shafts in the bush portion and bolted together at the flanges. Another scheme, often adopted for dynamo machines, is indicated in the accompanying sketch, and consists in casting a flange in



Shaft Coupling

one with the revolving spider, thus saving a double transmission of power through keys, first from the ordinary coupling to the dynamo shaft, and then again from the shaft to the dynamo spider. See COUPLING, FLEXIBLE; OLDHAM'S COUPLING; PLATE COUPLING.

Covered.—

['"Covered with insulating material' means adequately covered with insulating material of such quality and thickness that there is no danger.'—From definitions accompanying Home Office 1908 Regulations for Electricity in Factories and Workshops.]

Cp, the preferable abbreviation for candle power (which see).

Cr, the chemical symbol for chromium. See 'Chrome Steel' under STEEL.

Crab, Crane. See CRANE, ELECTRIC.

Cradle Suspension. See SUSPENSION OF TRACTION MOTOR.

Crane, Electric.—An electric crane is one in which the motive power is electricity. In the earlier electric cranes a single shunt-wound electric motor was mounted on some convenient part of the crane, and drove the various motions by means of friction clutches. Owing to the complication of the mechanical gearing the frictional losses were considerable, an efficiency of only 30 per cent being quite common. It is now usual to employ a separate series-wound motor, with simple speed-reduction gearing for each motion, thus lessening the mechanical losses and enabling efficiencies of 70 to 80 per cent to be secured, the increase of efficiency being an important advantage where the current is paid for by meter.

The principal types of electric crane are as follow:—

OVERHEAD CRANE.—This type of crane (illustrated in fig. 1) is used very widely.

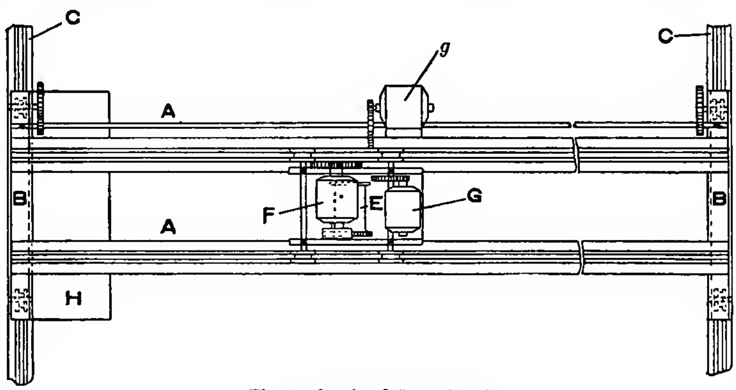


Fig. 1.—Overhead Crane (plan)

A pair of cross girders A A are supported on the end carriages B B. The wheels of the end carriages run on rails mounted on the *gantries* C C. The purpose of the crane is to lift, transport, and deposit loads anywhere within an area rather less than the width between the gantries, and of a length depending only on the length of the gantries.

Rails are laid on the cross girders, and a crab runs on these rails. The crab has two motions, each driven by its own motor. The hoisting motion, for lifting and lowering the load, consists of the drum E, driven through suitable gearing by the motor F. To traverse the crab along the cross girders, the motor G drives one pair of wheels, through gearing. For the purpose of travelling the crane along the gantry, the motor *g* is mounted at the centre of one of the cross girders, and from each end of the motor, a shaft is led to drive one wheel in each of the end carriages. The object in mounting the travelling motor at the centre of the cross girders is to obtain an equal amount of twist in both parts of the shafting, so as to avoid cross wind.

At one end of the crane a cage H is placed, containing the switches and controllers. The driver is stationed in this cage, the position of which gives him a clear view of the work.

Goliath Crane.—This is merely a variation of the last type. The end carriages run on rails, and the cross girders are supported by pillars from the end carriages and at the requisite height.

Locomotive Jib Crane (fig. 2).—The hook hangs from the end of the jib A, which

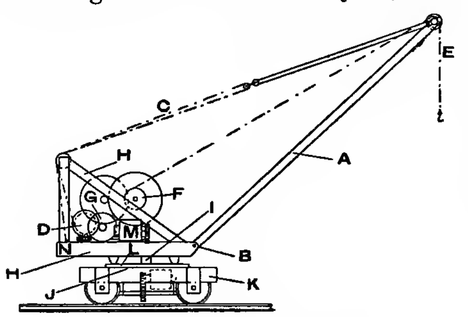


Fig. 2.—Electrical Locomotive Jib Crane

is supported by the piece B and rope C, which leads to the drum D. By winding-in or paying-out the rope C, the radius of the jib in the horizontal plane can be increased or diminished. The rope for hoisting the load is brought over a pulley at the head of the jib and led to the drum F. Drums D and F are usually arranged to be driven from the one motor, G, clutches being so arranged that when the motor is in gear with the one drum, it is out of gear with the other. The jib and hoisting gear are carried by the framing H, which turns upon the pin I, the turning or slewing being accomplished by means of the wheel J, which is secured to the platform of the truck K and pinion L (carried by bearings in the framing H), which is driven by the motor M. It is usual for the framing to be capable of making a complete circle.

The motor M is also used to drive the truck along the rails. A vertical shaft driven from this motor passes through the pin I, and drives one or both of the axles by means of bevel gear. Clutches are provided, so that the motor M may be used for slewing or travelling. The load is balanced by the weight N. A footplate for the driver is provided on the framing, just in front of the balance weight, and the controllers and clutch levers are placed conveniently to his hand.

The area served by a crane of this type has a width equal to twice the maximum radius of the jib, and a length depending on the length of rails laid.

Derrick or Scotch Crane (fig. 3).—The load hangs from the end of the jib A, which is supported by the pin B and rope C, which leads to the jibbing drum D, by which the jib can be raised or lowered. The load-rope E is led to the drum F. Drums D and F are driven by motor G. A clutch is provided, by which the drum D may be put in or out of gear with drum F. When D is out of gear, the drum F is used to lift or lower the load. When the two drums are clutched together they run in opposite directions, so that when drum D is hoisting the jib, drum F pays out the load-rope, and vice versa. Thus, whether the jib is being lifted or lowered, the load remains steady, and simply runs in or out in a horizontal line.

The jib and the motors and gearing are carried by the vertical mast H, which turns

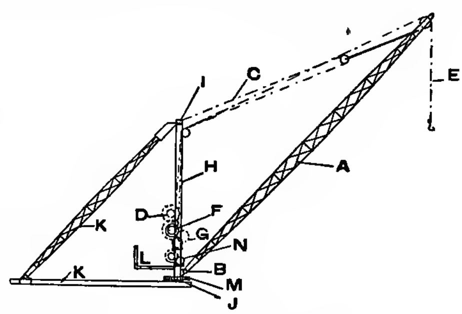


Fig. 3.—Electric Derrick Crane

in bearings I J in the framing K. The driver's platform L is also attached to the mast, and the various controlling switches and levers are placed on this platform.

To slew the mast and jib, a toothed wheel M is fastened to the framing and gearing. With this is provided a pinion, the shaft of which is carried in bearings on the mast, and is driven by the slewing motor N.

This type of crane will serve an area having a radius equal to the maximum horizontal radius of the jib, and forming a segment of a circle embracing an arc of rather less than 270 degrees.

SHEER LEGS, a type of lifting appliance used for handling extremely heavy loads, such as ships' boilers and heavy guns (fig. 4). The load-rope passes over a pulley at the head of the legs A, and is led to the winding drum B, which is driven by the motor C. The bottom of the back leg D is traversed by a screw E, driven by the motor F, so as

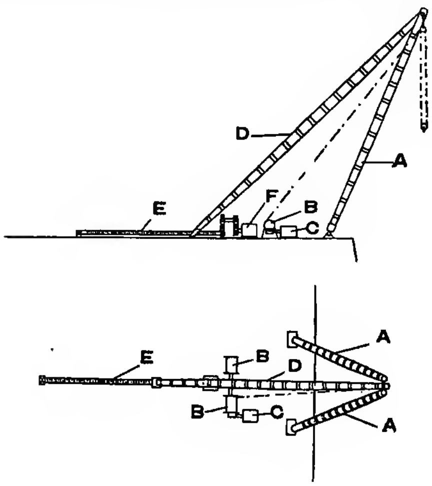


Fig. 4.—Sheer Legs

to traverse the load in or out. Occasionally a second hoisting drum and motor are provided to handle light loads at quick speeds.

It will be noted that with this type of crane, loads can only be picked up and deposited along a horizontal line which is a continuation of the centre line of the screw.

TRANSPORTERS are used chiefly for handling comparatively light loads at quick

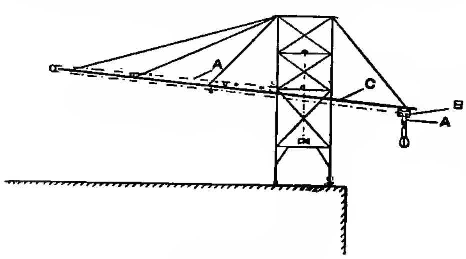


Fig. 5.—Transporter

speeds, and are employed largely for the conveyance of materials such as coal in bulk, in which case an automatic grab is hung on the load rope instead of an ordinary hook. The mode of operation is indicated in fig. 5. The grab being full, the electrically-driven drum winds in the load-rope A. The carriage B being held by a trigger at the bottom end of the beam C, the winding-in of the rope lifts the grab. When it is heaved right up to the carriage, it locks itself to it, and at the same time lets go the trigger. The carriage is pulled along the beam, but as the rope is now single-purchase, the carriage is pulled along at double the speed at which the load was hoisted. On arriving at the top end, the carriage is held by a trigger, and the grab is freed from the carriage. The motor is now reversed, and the grab, after being lowered a given distance, discharges its contents. The motor is again reversed, so hoisting the grab up to the carriage, to which it locks itself and frees the trigger. On reversing the motor, the carriage runs down the beam, and at the bottom end is caught by the trigger, while the grab is released and continues to run down till it plunges into the material, when all is ready for the commencement of a fresh cycle of operations. A complete cycle takes from $\frac{1}{2}$ to 1 min, and the load of the grab is usually from 1 to $1\frac{1}{2}$ tons. This type of crane is used simply to convey loads between two fixed points.

CABLEWAY (fig. 6).—A strong steel-wire rope is stretched between the towers B B.

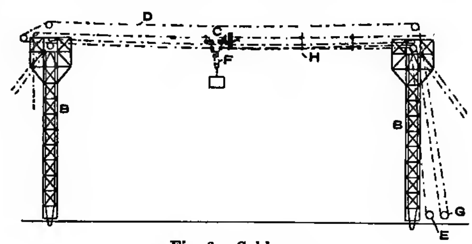


Fig. 6.—Cableway

On this rope runs the carriage C, pulled backwards and forwards by the hauling-rope D, which is operated by the capstan drum E. One end of the hoisting-rope F is secured to the carriage, and is led round the various pulleys shown and to the hoisting drum G. The slack of the hoisting-rope, when paying-out is supported by the carriers H. These carriers are dropped by the carriage when running from B to B, and are picked up again when returning, their position being determined by buttons of different size arranged on the rope.

Loads are hoisted and lowered by drum G, drum E being held by its brakes. To travel the load, the two drums are clutched together. Drum E then hauls the carriage along, while drum G takes in or pays out the hoisting rope, so that the vertical position of the load is unaltered.

This appliance will take up and deposit loads anywhere along a line directly underneath the main rope, and by means of *snatch blocks* it may be made to serve an area having a width of about 15 ft or so each side of the rope.

The forms of cranes in use are so numerous that it would be impossible to describe them all here, but it will be found that almost all of them contain motions and arrangements of the types described, varying only in the way in which they are combined.

Crane Motors.—For driving the travelling, traversing, and slewing motions of cranes, series-wound motors of a generally similar type to those used for electric traction give satisfactory results, this work being, in fact, a simple class of electric traction. The driving of the hoisting motion presents a more difficult problem, for though it is easy to lift the load up, it is not always so easy to get it down again in a satisfactory manner.

Automatic Electromagnetic Brake.—It is customary to fit the hoisting motion with an electromagnetic brake. This may consist of a band brake which is normally kept on by a spring or weight and released by an ironclad solenoid, or it may be a disk brake in which the disks are normally pressed together by a spring, an electromagnet being provided to pull back the pressure plate and release the disks. The coil of the solenoid or electromagnet is in circuit with the hoisting motor, so that when current is switched on to the motor the brake is released, and when it is switched off, the brake is applied. This makes an excellent safety device, but as it can only be right off or full on, it cannot be used to regulate the descent of the load when lowering.

In cases where the driver has access to the gear, as in locomotive jib cranes and derricks, an addition may be made to the electromagnetic brake in the form of a hand or foot release-lever, by which the brake can be released or its pressure regulated. Loads are then hoisted by the motor, and are allowed to run down by their own weight, the speed of descent being regulated by the brake. Where the driver operates the gear from a distance, the arrangement just described is not practicable, and some automatic or electrically-controlled arrangement must be used to check the speed of descent of the load.

Automatic Mechanical Brake.—A common arrangement is the automatic mechanical brake. The brake is usually of the disk type, and is arranged to allow the gear to run freely in the direction for hoisting, but holds it from running in the opposite direction, being applied by a screw, or it can be arranged to be operated automatically by the load. The brake is released by running the motor in the direction for lowering. As the motor releases the brake, the load tends to put it on again; consequently the speed of descent depends upon the speed of the motor, and this can, of course, be regulated by the driver by means of the controller.

Eddy-current Brake.—This type of brake is only used to a limited extent. It consists of a wheel, generally of copper or other metal of low electrical resistance, which is arranged to rotate between the poles of an electromagnet. The wheel is driven by the descending load, and eddy (or Foucault) currents are generated in it, which give rise to a retarding torque. The eddy currents and the consequent torque are regulated by varying the strength of the magnet by means of a regulating switch and resistance.

Rheostatic Brake.—For this form of braking, the controller is provided with several positions on the lowering side, called *brake points*. In these positions the controller alters the connections of the motor to those of a series dynamo, so that it generates current when driven by the descending load, the energy being absorbed by the controller resistance. The speed of lowering is regulated by varying the resistance.

Regenerative Control.—Instead of a series motor, a shunt-wound motor may be used to drive the hoisting motion. A shunt motor has the advantage that its speed can be efficiently regulated over a fairly wide range by inserting resistance in its field circuit. By this means considerable variation of speed in lifting and lowering may be obtained without the necessity of having variable-speed gear in the hoisting train, and when lowering, the shunt motor, if overhauled by the load, becomes a dynamo and feeds current back to the circuit, thus automatically controlling the speed of lowering. This system has been in use to a limited extent for some years, and is fully described in vol. clx, Proc.I.C.E., p. 368.

Collector Gear. — To convey current from the mains to the moving crane a collector gear, generally similar to that used for electric tramway work, is employed. For overhead cranes copper wires about $\frac{1}{4}$ to $\frac{3}{8}$ in. diameter are stretched along the gantry, being supported at the ends by Globe strain insulators. Trolley wheels or slides mounted on the end carriage make contact with these wires. From the trolley wheels or slides insulated cables are led to the switches and controllers, and to another set of trolley wires on the cross girders. Contact with these wires is made by sliders or trolley wheels on the crab, from which cables are led to the motors. For locomotive jib-cranes overhead or underground collector gear is used, similar to that used for tramcars. As derrick cranes only swing backwards and forwards through a portion of a circle, collector gear is not necessary. Connection from the supply mains to the moving part of the crane can be very satisfactorily made by means of flexible armoured cable.

Controllers. — The class of controller most commonly used for crane work is that known as the drum, or tramway, type. In these controllers the wires and cables are brought to a series of fixed contacts, usually arranged in a straight line. A series of corresponding contacts are attached to a revolving drum, and by rotating this drum into different positions the various combinations of connections for hoisting, lowering, &c., are obtained. (Ref. 'Die Hebezeuge', A. Ernst; Proc.I.C.E., vol. clx, p. 368; Journ.I.E.E., vol. xxxvi, p. 290; 'Electric Cranes', Böttcher.) [C. W. H.]

Crane Controller, Electric. See Crane, Electric.

Crane Motor. See Crane, Electric.

Crank-effort Diagram, the diagram indicating the variation in the twisting effort upon an engine shaft at various stages during a complete cycle of operations. See Torque Diagram of an Engine.

Cranks in Synchronism. — In some reciprocating engine sets it is difficult to run properly in parallel unless the cranks of the various engines are similarly situated at any instant of running. By arranging this, the periodic cyclic irregularities in speed occur together, and no excessive cross-currents flow from this cause. To arrange for crank-synchronism the cranks actuate an electrical contact at one position of their path, and when the cranks actuate their contacts at the same time, the contacts being in series, a bell-signal is given on the switchboard. See Cyclic Irregularity.

Crater. See Arc.

Creeping. See Magnetic Creeping; Shunt Running.

Creosoting. See 'Wooden Line Poles' under Line Poles.

Crest, a term recently proposed by Kapp to indicate the maximum value of an alternating quantity. Thus, the crest value of an alternating current is equal to $\sqrt{2}$ times the effective value.

Critical Angle. See Reflection, Total Internal.

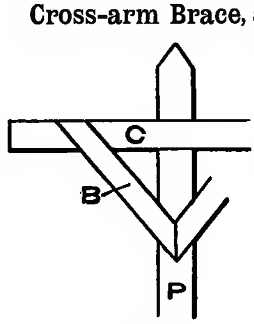
Critical Damping. See Dead-beat Electrical Measuring Instruments.

Crompton Potentiometer. See Potentiometer.

Crookes' Tube. — Sir William Crookes was the first to investigate the electrical discharge in very high vacua. Hence vacuum tubes in which the gas-pressure is extremely low are frequently called *Crookes' tubes.* Crookes demonstrated the fact that at very low pressures the free paths of the molecules become so appreciable that it is possible, by electric forces, to guide the molecules into streams. The discovery of the difference of pressure produced by the incidence of light on blackened and polished surfaces led him to the invention of the *radiometer*, which consists of a small set of vanes free to rotate in a vacuum, and which consequently move when exposed to light. See also Vacuum Tube, Geissler Tube, and Hittorf's Tube.

Cross Ampere Turns, Armature. See Armature Reaction.

Cross-arm Brace, a strengthening piece between a pole and a cross arm (see fig.), in which B is the cross-arm brace, P the pole, and C the cross arm.



Cross-arm Brace

Cross Arms. See 'Wooden Line Poles' under Line Poles.

Cross Bond. See Return Circuit in Electric Traction.

Cross Bonding. See Bonding Rail.

Cross-connected Commutator. See COMMUTATOR.

Cross-connecting Board, a board fitted with two sockets and with two plugs joined together by insulated flexible cable, so that any two sockets with their attached circuits may be placed in electrical connection. Other sets of plugs may be used on the same board. This arrangement was formerly frequently adopted to connect circuits of a large number of arc lamps in series to various generators as required; but since the abandonment of this system of arc lighting such cross connecting boards have become rare, at least in Britain.

The term is also sometimes applied to a switchboard or panel provided with double sets of bus-bars at right angles to one another, with sockets at the points where the bars cross one another, so arranged that, by means of plugs, any bar can be connected to any one of several other bars. (Ref. 'Electrical Engineer's Pocket Book', Foster.)

Cross Connections. See CONNECTIONS, CROSS.

Cross Field. See ARMATURE REACTION.

Cross Flux. See ARMATURE REACTION.

Cross Induction. See ARMATURE REACTION.

Cross Magnetising Effect. See ARMATURE REACTION.

Crown of Poles.—In inductors and other early machines of the Mordey and Ferranti types a series of polar projections, all of the same magnetic sense, were presented to one side of the armature, the emf being generated through the difference in magnetic intensity at the centre and between the poles. Such a ring of polar projections was called a *crown of poles.*

Crown Rail Bond. See BOND.

Crystallate, the trade name of a moulded composition manufactured in several qualities. The better qualities are hard, but inclined to be brittle. They will take a fairly good polish, and will not absorb moisture. See 'Moulded Insulator' under INSULATOR. [H. D. S.]

Cu, the chemical symbol for Copper (which see).

Cu, the preferable abbreviation for cubic.

Cubic Centimeter (preferable abbreviation, cu cm), the volume occupied by 1 g of water.

Cubic Decimeter (preferable abbreviation, cu dm), the volume occupied by 1 kg of water. 1 cu dm = 1 liter.

Cubic Meter (preferable abbreviation, cu m), the volume occupied by 1 metric ton (1000 kg) of water.

Cubicle (or Cellular) Type of High-tension Switchboard. See SWITCHBOARD, CUBICLE (OR CELLULAR) TYPE.

Cumulative Compound Winding. See WINDING, CUMULATIVE COMPOUND.

Current, one of the components of electrical power. The unit of current is the ampere. The other component of electrical power is pressure, of which the unit is the volt. These statements are only rigorously true for continuous electricity (see ELECTRICITY, CONTINUOUS). For alternating electricity (see ELECTRICITY, ALTERNATING) the product of the values of the current and the pressure *at any instant* is the electrical power at that instant; but if the *effective* (rms) values of the current and pressure are taken, their product must be multiplied by the power factor (which see) in order to obtain the electrical power.

Current, Alternating. See ALTERNATING CURRENT.

Current, Average.—An ac is a current which periodically increases in strength from zero to a maximum, and then decreases to zero, reverses its direction, grows to a maximum in the reverse direction, and again decreases to zero. The value of the current passes through this cycle of changes a number of times per sec, equal to the frequency (which see) in cycles per sec. The arithmetical mean of these values (irrespective of the direction of the current) is termed the average current. For a sine-wave current the average value is equal to 0·635 times the crest value. Since the effective current (which see) is equal to 0·707 of the crest current (for a sine-wave current), the effective current is 1·11 times as great as the average current, In other words, the form factor (which see) of a sine-wave current is 1·11.

Current, Capacity. See CAPACITY CURRENT; CURRENT, CONDENSER; CURRENT, LEADING.

Current, Charging. See CHARGING CURRENT; FARAD; CAPACITY CURRENT; CURRENT, CONDENSER; CAPACITY.

Current, Component.—An ac following a sine law may be represented as a vector rotating in the period of the alternation. Two or more such currents, in different phases, but of like periodicity, superposed in a conductor, have a resultant which is represented by that of the vectors of the several currents, compounded according to the parallelogram law. Similarly, any current can be regarded as compounded of components in any desired phases. Thus it is common to regard an ac as having a component in phase with the emf (the power component), and a component in quadrature therewith (the wattless component).

[F. W. C.]

Current, Condenser, denotes the current flowing in an ac system due to the electrostatic capacity between the different parts of the circuit. Such a current is a 'wattless' or 'idle' current, and its phase is 90° in advance of that of the impressed emf. Its action is such as alternately to transfer energy from the generator to the dielectric, and return it again to the generator. See CURRENT, LEADING; FARAD; CAPACITY CURRENT; CAPACITY. [R. C.]

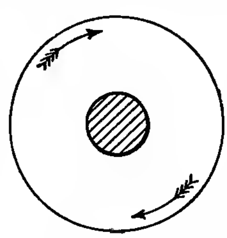
Current, Conduction. See CURRENT, ELECTRIC.

Current, Constant. See CONSTANT CURRENT.

Current, Continuous. See CONTINUOUS CURRENT.

Current, Core-loss. See CORE-LOSS CURRENT.

Current, Direction of.—Although the electric current is doubtless a kinetic phenomenon, we have no knowledge of the manner or direction of the motion. What is known as the direction of the current is an arbitrary convention. It is such that the direction of the current bears to the direction of the magnetic force produced by it, the same relation as the direction of the axis in a right-handed screw bears to the direction of rotation required to carry the screw along the axis. Thus in the figure, if the magnetic force about the conductor whose section is shown is in the direction of the arrows, the direction of the current is away from the spectator. See also CORKSCREW RULE; FLEMING'S RULE; AMPERE'S RULE.



Direction of Current

Current, Displacement.—When current begins or increases in a conductor, a certain quantity flows into the dielectric surrounding the conductor, the reverse action occurring when current decreases, or ceases. The effect of this is to produce a leading, as opposed to a lagging (see ALTERNATING CURRENT) current. See also CURRENT, ELECTRIC; ELECTRICITY. (Ref. 'The Alternate Current Transformer', Fleming.)

Current, Earth. See TERRESTRIAL MAGNETISM.

Current, Eddy. See EDDY CURRENT.

Current, Effective. See 'Root Mean Square Current' under ROOT MEAN SQUARE.

Current, Electric, the cause of the phenomena observed when an emf is applied to a conductor (see ELECTROMOTIVE FORCE), these being due to the flow of electricity in the conductor, whatever electricity may be. See ELECTRICITY.

A current may be conceived to flow through a conductor under the stimulus of an emf, in a manner somewhat similar to that in which water would percolate through a porous medium under the stimulus of hydrostatic pressure—the medium being bounded by impervious material except where the water enters or leaves. The energy of the system is in part dissipated against the resistance of the conductor, although the current flows in greatest measure through the paths of least resistance between the electrodes. In fact, a given current chooses such paths between the electrodes as to dissipate a minimum of energy against resistance. To this extent the current resembles the percolating stream of water. It also possesses energy corresponding, in some respects, to the kinetic energy of moving matter (see INDUCTION, SELF-). In the region surrounding a current-carrying conductor, however, phenomena appear which have no analogies in the flow of water through a porous medium. In this region the current behaves somewhat as if each of its lines of flow were a vortex-whirl in an incompressible fluid—the lines of flow of the fluid corresponding to the lines of magnetic force about the conductor.

When an emf is applied to a dielectric, a transient current takes place, known as a *displacement current* (see CURRENT, DISPLACEMENT; ELECTRICITY), which gives rise to the same magnetic phenomena as a *conduction current.* Taking account of both conduction and displacement currents, the total flow of electricity into any closed surface in space is zero; that is to say, electricity flows like a continuous incompressible fluid.

All indications tend to prove that the electric current is in some way a kinetic phenomenon, and not a mere state. (See Maxwell's 'Electricity and Magnetism', § 569.)

Mathematically, the electric current is a vector of the nature of a flux. As the flux is like that of a continuous incompressible fluid, the total flow through every surface bounded by a given closed curve is the same at every instant. It follows that the total flow may be expressed in terms of an intensity function to be associated with the bounding curve. This function is known as the *magnetic force*.

The practical unit for the measurement of current is the *ampere* (which see). [F. W. C.]

Current, Equalising. See EQUALISING BARS AND CABLES.

Current, Exciting. See EXCITATION.

Current, Fusing. See FUSING CURRENT.

Current, High-pressure.—A h pr current is defined by the Home Office as one in which the pressure at the terminals is between 650 and 3000 volts.

EXTRA H PR CURRENT.—An extra h pr current is defined by the Home Office as one the pressure of which exceeds 3000 volts.

MEDIUM-PRESSURE CURRENT.—A medium-pressure current is defined by the Home Office as one in which the pressure at terminals is between 250 and 650 volts.

L PR CURRENT.—A l pr current is defined by the Home Office as one in which the pressure at the terminals does not exceed 250 volts.

Current, Induced. See CURRENT INDUCTION.

Current, Induction. See CURRENT INDUCTION.

Current, Intermittent.—(1) A current which, by some automatically controlled device, is put on and off at regular intervals, as for instance in the primary of an induction coil, or in connection with illuminated advertisements. (2) A current which, through some defect in machinery, is caused to go on and off.

Current, Leading, denotes an alternating current whose phase is advanced with respect to that of the pressure applied to the circuit. The effect of a leading current is produced either by electrostatic capacity in the system, or by over-excited synchronous motors connected to the system. See CURRENT, CONDENSER; CAPACITY CURRENT.

Current, Magnetising. See MAGNETISING CURRENT.

Current, Make-and-break, current induced by mutual or self-induction in a circuit by the change of magnetic energy stored in the field in the form of magnetic flux, owing to the starting or stopping of a current. The action may be due to change in the field of a circuit, on the circuit itself (self-induction), or to the action of the field on another circuit (mutual induction; transformer action). At make, current is in the opposite direction to the inducing current; at break, in the same direction. (Ref. 'Electrical Researches', Faraday). See CURRENT INDUCTION; CURRENT, SECONDARY.

Current, Negative. See CURRENT, RETURN.

Current, Normal. See NORMAL CURRENT.

Current, Oscillating. See OSCILLATING CURRENT; DISCHARGE, OSCILLATORY.

Current, Outgoing, the current leaving the station from the positive terminals of the generators, also known as the *positive current*, or *current of positive direction.*

Current, Positive. See CURRENT, OUTGOING.

Current, Primary. See PRIMARY CURRENT.

Current, Pulsating.—A pulsating or *undulatory current* is one which rises and falls in a regular manner, and may be either unidirectional or alternating.

In the '1907 Standardisation Rules of the A.I.E.E.', the definition of pulsating current is as follows: 'A pulsating current is a current equivalent to the superposition of an alternating current upon a continuous current'. In interpreting this definition, the A.I.E.E. definition of continuous current (which see) must be kept in mind.

Current, Rectified, a term applied to the current derived from any device which suppresses, reverses, or transforms the negative half of an ac wave in such a way that the resultant current is always unidirectional, although not necessarily steady, but may pulsate.

Such currents are derived from the Ferranti commutating rectifier, the Nodon electrolytic rectifier, the mercury-arc rectifier, and machines of the permutator type (which see). See RECTIFIER.

Current, Return.—The current returning to the negative terminal of a generator is known as the return or negative current.

Current, Reversal of. SEE REVERSAL OF CURRENT; REVERSING A CURRENT.

Current, Secondary.—A secondary current is one generated by induction in some form of transformer, rotary or static, from another current known as the primary. See CURRENT INDUCTION; CURRENT, MAKE-AND-BREAK.

Current, Short-circuit, the current in a generator or transformer when the terminals are short-circuited by a conductor of negligible resistance. The current in the primary of an ac motor when standing still with short-circuited secondary winding.

NORMAL SHORT-CIRCUIT CURRENT of an alternator is the current flowing in the armature circuit when the terminals are short-circuited, the speed and excitation being such as will give normal emf at the terminals if normal full-load current is being taken from the machine. ' See CURRENT RUSH.

Current, Thermoelectric. — If two wires of different materials be joined at their ends so as to form a circuit, an emf is in general created in the circuit by keeping one of the junctions at a higher temperature than the other, and a current flows in consequence. Though this emf is usually very small, its presence is frequently troublesome when accurate measurements are being made. For a mean temperature of 20° C. it amounts, for copper-iron, to about 17×10^{-6} volts per degree C.; for platinum-copper, $0{\cdot}8 \times 10^{-6}$ volts; for mercury-copper, 22×10^{-6} volts; and for bismuth-selenium, which is the maximum known, 900×10^{-6} volts; for bismuth-antimony, 100×10^{-6} volts. The emf varies not only with the difference of temperature of the junctions, but also with the mean of their temperatures. (See Tait, Trans.Roy.Soc. Session 1870–71, p. 308, also Dec. 18, 1871.)

Though many attempts have been made to use this property of metals as a source of current, none have been successful, chiefly on account of the deterioration of the junctions, due probably to slow diffusion of the one metal into the other. The pressures obtainable are also very low.

Current, Transformer, a current in any apparatus which is induced in a coil or coils by 'transformer action', *i.e.* by electromagnetic induction from another coil or coils. See CURRENT INDUCTION; CURRENT, MAKE-AND-BREAK; CURRENT, SECONDARY.

Current, Undulatory. See CURRENT, PULSATING.

Current, Unidirectional. See UNIDIRECTIONAL CURRENT.

Current, Unit. See CURRENT, ELECTRIC; also AMPERE.

Current, Wattless, an ac which conveys no power; the component of an ac which is in quadrature with the emf. See CURRENT, COMPONENT.

Current Balance. See AMPERE BALANCE.

Current Density.—The amount of current flowing in any conductor, divided by the cross-sectional area of the conductor, is usually expressed in amp per sq cm or per sq mm, and is termed the current density.

Current Distribution, the way in which a current divides into different parts of a conductor, or amongst different conductors connected in parallel.

For a single conductor the distribution is usually uniform, *i.e.* the current density is the same at all points of any section of the conductor. In special cases, however, the distribution is not uniform. Thus in a bar carrying ac, the current density is greatest at the outside of the bar, and decreases towards the centre (see SKIN EFFECT). In plates or blocks, of which the section is large as compared to their length, the current distribution will vary according to the position of the terminals. In networks of conductors the distribution varies according to the resistance, and in the case of ac according to the impedance of the separate conductors.

CURRENT DISTRIBUTION IN WINDINGS, current distribution in the different windings of a generator or motor. In the case of cc armatures having several circuits in parallel, one or more of these circuits may take more than its proper share of the current, owing to some want of symmetry in the magnetic fields, or for some other reason. This frequently causes commutation troubles, and, in the case of lap-wound armatures, is provided against by the use of equaliser rings. See CONNECTIONS, EQUIPOTENTIAL.

In the case of ac windings, the current distribution is a function of the time.

UNIFORMLY DISTRIBUTED CURRENT.—A cc, or an ac of lf, flowing in a conductor, is carried equally by all parts of that conductor, so that the current density is equal over the whole of the sectional area. Currents of hf are not uniformly distributed throughout the section of their conductors, the greater part of the flow taking place in the portion near the surface, the inner central portion of the conductor carrying little or no current. See SKIN EFFECT.

Current Induction.—When a continuous current flows in a wire, a magnetic field is set up surrounding that wire. Should a second wire, having its ends joined so as to form a complete circuit, be brought within this field, a current, known as an induced current, will flow in it, so long as it is kept in motion, approaching to or receding from the first wire.

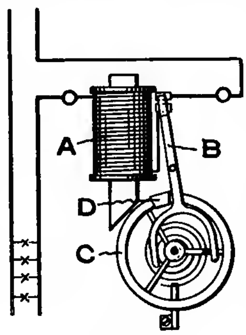
The same effect will be produced if the second wire remains stationary, and the current in the first wire be switched on or off, or varied in its strength.

INVERSE INDUCED CURRENT.—When the second wire is approaching the first wire, or when the current in the first wire is beginning or increasing in value, the current in the second wire flows in an opposite direction to that in the first wire, and is known as an inverse induced current.

DIRECT INDUCED CURRENT.—On the other hand, when the second wire is receding from the first wire, or when the current in the first wire is ceasing, or decreasing in strength, the current in the second wire flows in the same direction as that in the first wire, and is known as a direct induced current.

EXTRA CURRENT.—If, however, we have only a single wire, we still obtain inductive effects. Thus when current commences to flow in the wire, an inverse induced emf is set up opposing the flow of current, and when current is cut off, a direct induced emf is set up, the interruption of which causes a spark at the switch. Where, instead of a single wire, we have a coil of wire of many turns surrounding an iron core, these effects become very marked, the current, when switched on, being materially delayed in attaining its full value, while when switching off, a destructive spark is caused. These self-induced currents are occasionally spoken of as extra currents. The destructive spark which occurs when breaking the circuit may be materially reduced by the use of a non-inductive resistance. See RESISTANCE; CURRENT, MAKE-AND-BREAK; CURRENT, SECONDARY.

Current Limiter.—A term applied to a device whereby, if a consumer switches on more lamps than the number agreed upon, and for which the device is adjusted, the circuit will automatically either be intermittently interrupted, thus forcing the consumer to switch off some lamps in order that the remaining lamps shall burn steadily, or else a resistance is automatically switched into circuit, greatly reducing the brilliancy of the lamps. Still other principles have been employed for accomplishing this object.



Current Limiter

A device of this class is shown in the fig., where A is an electromagnet in series with the switch B, which can be opened by motion of the switch-arm on its pivot. C, an oscillating balance wheel, has a locking lever which is released when the current in A exceeds the agreed-upon value, and the armature, D, on the wheel, is attracted at the same time, thereby operating the switch-arm and cutting out the lights intermittently until the current is sufficiently reduced. See HANDCOCK AND DYKES LIMIT INDICATOR.

Current Meter. See AMMETER.

Current Recorder. See INSTRUMENT, RECORDING.

Current Reverser, a device for changing the direction of the current in a circuit (see SWITCH, REVERSING; CONTROLLER). A particular type is the reverser used in connection with multiple-unit systems of traction equipment. This consists of switch-contacts for reversing the direction of the current through the motors, and consequently reversing the direction in which the train runs, the moving portion of the switch being operated electromagnetically by a solenoid or solenoids, or electro-pneumatically by a solenoid-controlled valve, under the control of the master controller, by which all the movements of the train are regulated. Each coach has its own reverser, and as the latter generally changes the connections to the motors only when the circuit is open, no magnetic blow-out or arc-shield need be provided. (Ref. 'Electrical Traction', Wilson and Lydall.)

Current Rush, a flow of current of transitory nature and abnormal magnitude. For example, on suddenly closing the circuit of an unloaded ac transformer, it sometimes occurs that the current at first rises to a value much in excess of the normal magnetising current, but this abnormal current rapidly subsides, until the normal value has been reached. Similarly, if an alternator be suddenly short-circuited, the initial short-circuit current may be greatly in excess of the value which obtains when the steady state has been reached. [M. B. F.]

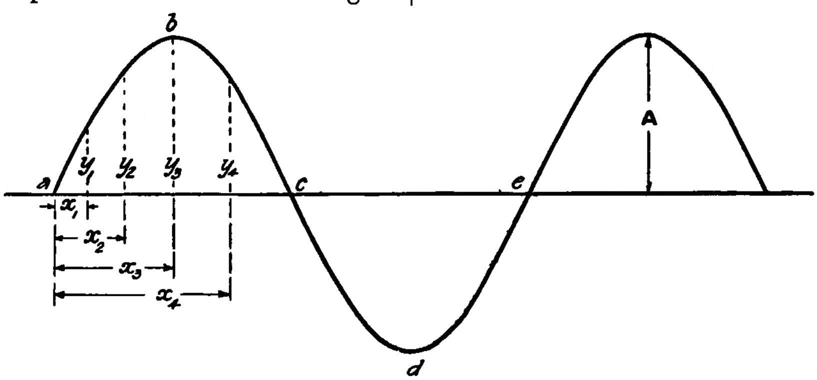
Current Transformer. See TRANSFORMER, INSTRUMENT.

Curve.—A curve is a means of graphically representing the variation of one quantity with relation to another. A common example is that of the meteorological charts, giving the variation of the thermometer or barometer reading. Here we have horizontally a scale of time, and at any given time we set up a perpendicular of length proportional to the reading of the instrument. This gives us a point on the paper, and by obtaining a series of such points we can draw a line or curve through them. The advantages of such curves are:

(*a*) That they enable the variation of a quantity, or the performance of a machine, to be seen at a glance;

(*b*) that they indicate in many cases whether there are any errors of observation, and allow of their compensation; and

(*c*) that wherever any definite law connects the two quantities, it can be found from the curve.



Curve of Sines

In curve-plotting, the distances measured horizontally are termed *abscissæ*, and those measured vertically are termed *ordinates.* As a general rule, quantities which are known, such as time or scale readings, are plotted horizontally, and the measured quantities, such as pressure, temperature, voltage, &c., are plotted vertically. Where a number of quantities for the same machine are determined, they are frequently plotted together on the same sheet, as in the motor-test curves accompanying the definition of MOTOR-PERFORMANCE CURVES.

POLAR CURVES.—In the majority of cases, curves are plotted in the way just mentioned, *i.e.* with rectangular co-ordinates, but in special instances where the quantity measured differs in different directions in space, the method of plotting in polar co-ordinates is sometimes preferred. In this case, a central point or *pole* is selected on the paper, and the value of the quantity measured, such as the cp of a lamp, is set out along a line drawn at the same angle with the horizontal as that at which the quantity has been measured. An illustration of this method of plotting will be seen in fig. 9 of the definition of CURVE, CHARACTERISTIC.

Curves are sometimes termed *characteristics*, and sometimes *characteristic curves.* The term is more frequently employed in connection with dynamo-electric machinery.

CURVE OF SINES.—If y and x be variables related by the equation $y = A \sin x$, where A is any constant, and if the successive values of x be plotted horizontally, while the corresponding values of y be plotted vertically, the resulting points will lie upon a curve of sines. Thus the curve $a\ b\ c\ d\ e$ in the figure, is a curve of sines, and

$$y_1 = A \sin x_1,$$
$$y_2 = A \sin x_2,$$
$$y_3 = A \sin x_3, \text{ \&c.}$$

The constant A is called the *amplitude*, and is the maximum height of the curve, measured from the zero line. A represents the crest value of the curve.

Curve, Characteristic.—The term *characteristic* is applied to a curve which exhibits the typical behaviour of any form of machine or other device. The term probably originated with Marcel Deprez, who in 1881 applied the term *characteristic curves* to the curves obtained by Dr. Hopkinson in 1879, which showed the relation between the pd and the current of a dynamo run at a constant speed, and thus exhibited the essential difference between the behaviour of series, shunt, and separately-excited generators. Other curves which have been termed *characteristics* are those connecting the open-circuit emf and the short-circuit current of dynamos and alternators, with the excitation; those giving the relation of torque to speed (*torque curves* and *speed curves*) in motors; the relation of current, cp, and efficiency to pressure in glow lamps, and the relation of pd to current in arcs. (Ref. 'La Lumière Electrique', Dec., 1881; 'Dynamo-Electric Machinery', S. P. Thompson, 7th ed., vol. i, p. 323.) See CURVES, LOAD, OF CENTRAL STATIONS.

EXCITATION CURVE, a curve showing the relation between the emf of a generator run at constant speed and the exciting current. Such curves are obtained by connecting a

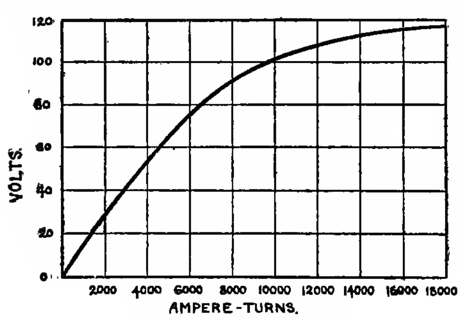


Fig. 1.—Excitation Curve

high-resistance voltmeter to the terminals of the generator, which is separately excited from an external source through an ammeter. The excitation curve is obtained by plotting the values of the exciting current (or mmf) horizontally, and of the corresponding pressures vertically. As the emf of a generator run at constant speed is proportional to the magnetic flux passing through the armature, it follows that this excitation curve is of the same shape as the curve of magnetisation of the magnetic circuit (see MAGNETISATION CURVE). The curve, therefore, rises rapidly at first as the current is increased, and afterwards bends over as the iron becomes saturated. The rise is, however, less steep than that of an ordinary magnetisation curve of a specimen of iron, owing to the air gap in the machine. The procedure for obtaining the curve and the form of the curve is similar in the case of either an alternator or a cc generator. The excitation curve is equivalent to the no-load characteristic or no-load saturation curve. An excitation curve of a cc generator is given in fig. 1.

OPEN-CIRCUIT CHARACTERISTIC, a term generally employed for the curve showing

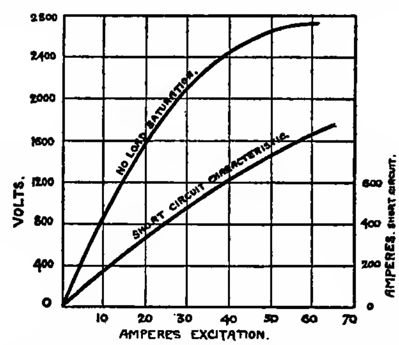


Fig. 2.—Open- and Short-circuit Characteristics of an Alternator

the relation of the emf generated in an alternator armature to the exciting current on no load when run at normal speed. It therefore corresponds to the *excitation curve* or *magnetisation curve* of a generator, and it is sometimes also known as the *no-load saturation curve*. It is obtained, as with cc machines, by exciting the machine to various degrees through an ammeter, and taking corresponding readings of an alternating-current voltmeter connected to the terminals of the machine when run at normal speed. The upper curve in fig. 2 is a typical open-circuit characteristic for an alternator.

SHORT-CIRCUIT CHARACTERISTIC, a curve showing the relation of the current produced in the armature of an alternator when short-circuited through an ammeter of negligible resistance and inductance to the exciting current. It therefore shows the excitation required to produce any given current in the alternator windings when the demagnetising effect and the inductance of the armature are taken into account. A typical short-circuit curve is shown in fig. 2, below the open-circuit characteristic. From a knowledge of these two curves, various methods have been proposed for pre-determining the regulation of a machine in service at various loads and at various pf. Prominent among these methods are those of Rothert, Behn-Eschenberg, Hobart and Punga, and Torda-Heymann (which see).

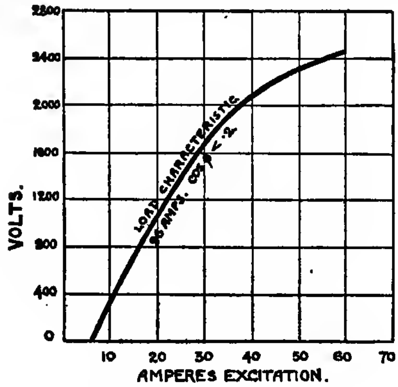


Fig. 3.—Load Characteristic

LOAD CHARACTERISTIC, a term generally employed to represent the relation of the pd at the terminals of an alternator armature, to the exciting current, for a fixed armature current at a fixed pf, when the machine is running at normal speed. It is therefore similar in form to the no-load characteristic, but is, as a rule, lower, owing to the armature reaction and the drop in the armature. Fig. 3 shows a load characteristic corresponding to a pf of 0·2, for the same alternator as in fig. 2 above.

CORE-LOSS CURVES.—These curves are used to represent the variation of the loss of power in the cores of generators, motors, or transformers, either with the induction density in the iron or with the load. The core loss is made up of two parts—the hysteresis loss, which is proportional to the volume of the iron, the frequency of the cyclic variation, and to the 1·5 or 1·6 power of the maximum induction density; and the eddy current loss, which is proportional to the square of the frequency and the square of the maximum induction density, and is also dependent upon the construction of the core. Fig. 4 shows a typical core-loss curve for a transformer, and another curve for a core in which the magnetism is rotating relatively to the iron, as in an armature.

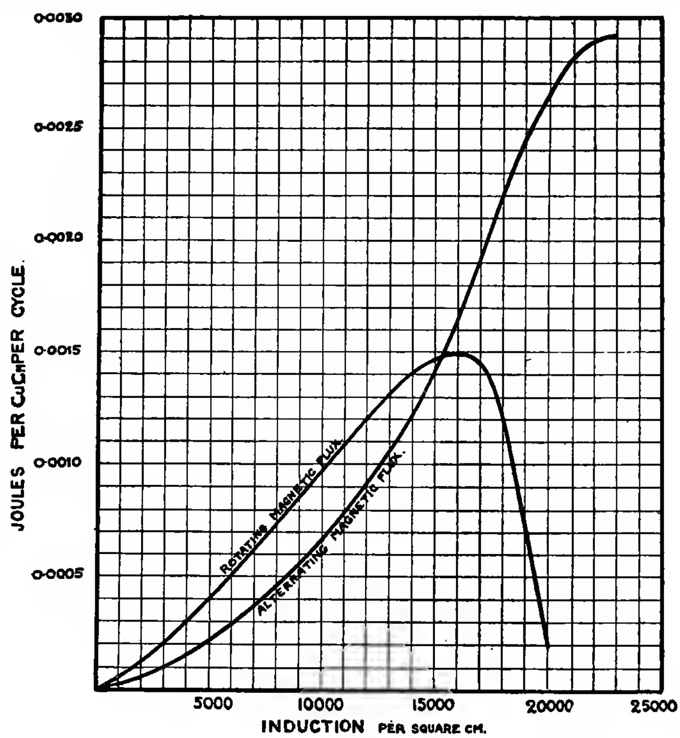


Fig. 4.—Core-loss Curves

EMF CURVE.—This term is generally used to imply the curve showing the relation of emf to time in an alternator. It is obtained either by an oscillograph or by an ondograph, or by a contact-maker method, such as that of Joubert. The ideal alternator should have an emf curve which is a perfect sine wave, but in practice this form is usually somewhat distorted, and there are frequently small irregularities due to the teeth of the alternator, which are termed harmonics, and which may give rise to resonance troubles. Figs. 5 and 6 show two typical wave forms for alternators.

DROOPING AND RISING CHARACTERISTICS.—Terms used to indicate the behaviour of a generator run at constant speed. In electric lighting by glow lamps, it is required that the pressure at the lamp terminals should be kept constant. With a series-wound generator the pressure rises as the current is increased, while with a shunt-wound machine

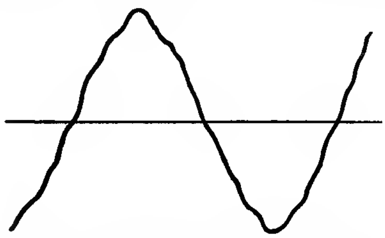


Fig. 5.—1600-kw Lahmeyer Alternator Open-circuit pd

it drops away. Consequently by combining a shunt and a series winding in suitable proportions, it is possible to make the rise due to the series winding compensate for the fall in pressure occurring with a shunt winding, and such a machine is said to be *compound*

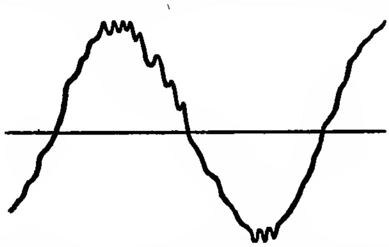


Fig. 6.—1500-kw Brown-Boveri Alternator Open-circuit pd

wound, or *compounded.* If the series winding is more than sufficient to compensate for the fall in pressure occurring with the shunt winding, the machine is said to be *over compounded*, and it will have a *rising characteristic;* while, if, on the contrary, it is

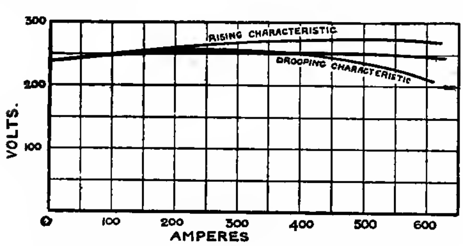


Fig. 7.—Drooping and Rising Characteristics

insufficient to compensate for the shunt, it is said to be *under compounded*, and it will have a *drooping characteristic.* Fig. 7 shows examples of such characteristics.

Curve of Distribution of Potential in Armature or Around Commutator, a curve used to represent the variation of the emf in a single armature coil, or the total pd between one brush and any commutator segment round the armature or commutator.

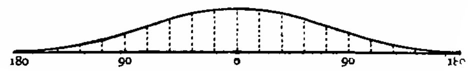


Fig. 8.—Curve showing Distribution of Potential in Armature (rectangular co-ordinates)

For the first purpose, two auxiliary brushes are so arranged as to touch the commutator, with an interval between them equal to the

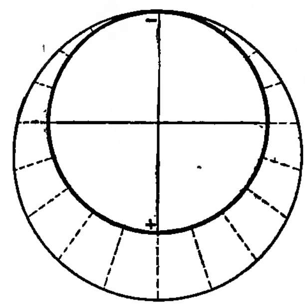


Fig. 9.—Same as fig. 8 but in Polar Co-ordinates

distance between the centres of the commutator bars, and these two brushes are connected to a voltmeter. When this pair of

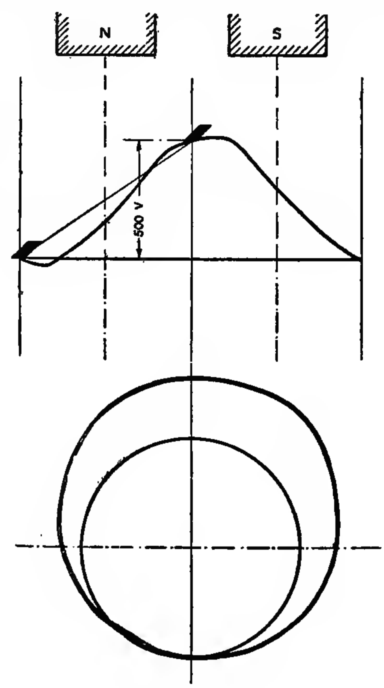


Fig. 10

brushes is moved round to various positions on the commutator, the reading of the voltmeter varies from a very low value at the main brushes to a maximum somewhere between the two main-brush positions. Figs. 8 and 9 show how the emf in the coil should vary in an armature rotating in a uniform field with the brushes in the neutral position, the former being plotted in rectangular coordinates, and the latter as a polar curve.

In the second method of determination, a single auxiliary brush only is used, and a voltmeter is connected between one of the ordinary brushes and the auxiliary brush, which is moved to different positions round

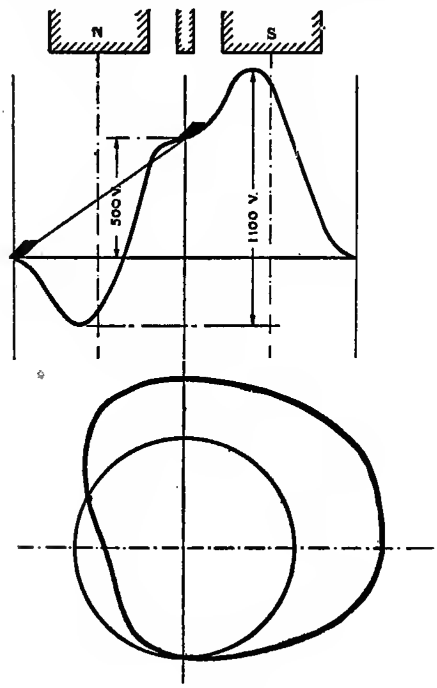


Fig. 11

the commutator. For the ideal machine the curves taken in this way will be as already shown in figs. 8 and 9. The curves in fig. 10 are for an actual machine under load showing the effect of field distortion, and those in fig. 11 are for a variable-speed machine with commutating poles when running at its highest speed, showing that considerable irregularities in the distribution of potential can be caused in practice, especially by the commutating poles, in the case of variable-speed motors of wide speed-range, where the field is very weak at the maximum speed. This is of considerable importance in its effect on sparking. See MOTOR-PERFORMANCE CURVES; CONTINUOUS-CURRENT GENERATOR CHARACTERISTICS. [C. V. D.]

Curve of Magnetisation or Saturation. See MAGNETISATION, CURVE OF; CURVE, CHARACTERISTIC.

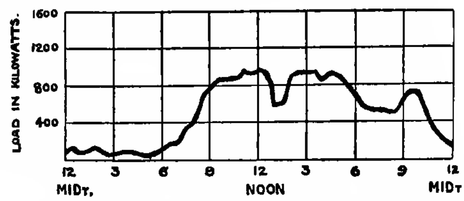


Fig. 1.—Load Curve of Lighting Station in Summer

Curves, Load, of Central Stations.—These curves are used to represent the varia-

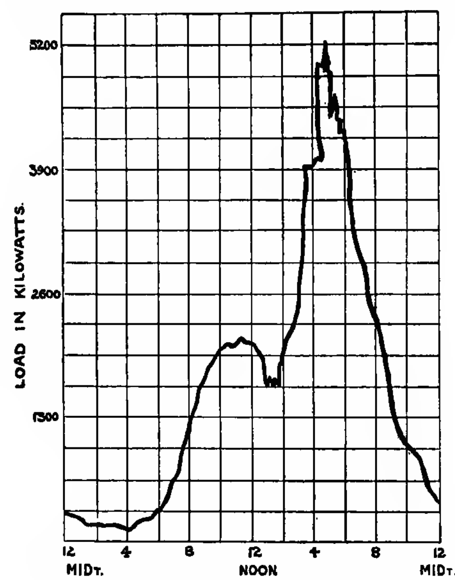


Fig. 2.—Load Curve of Lighting Station in Winter

tion of the load or output from a generating station, with time. Figs. 1 and 2 show typical

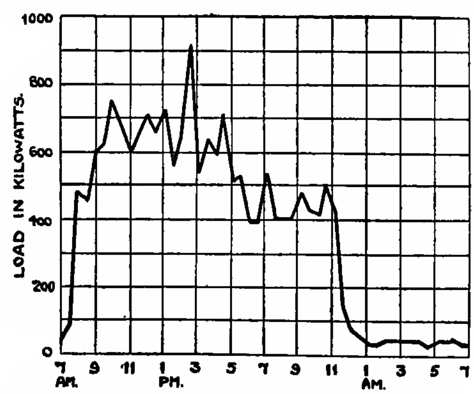


Fig. 3.—Load Curve for Traction Station (Dublin United Tramways, Ringsend Station)

load curves for summer and winter for a lighting station, and fig. 3 for a traction station. Such curves enable the following quantities to be determined:—

The maximum or *peak* load.

The average load, being the mean height of the curve.

The load factor, or the ratio of the average to the peak load.

The total output for any given time, which is equal to the total area of the curve for that time. See also CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

[C. V. D.]

Curve-tracer, Ewing's. See EWING'S CURVE-TRACER.

Cut-off Points in Discharge.—The pressure of a battery will fall as a discharge is taken from it, the drop being more rapid as the rate of discharge is increased. Although at high rates of discharge, a lower final pressure is usually allowable than at low rates of discharge, the pressure per cell should not be taken below the cut-off point recommended by the makers. See ACCUMULATOR; ACCUMULATOR PLATES; BATTERY CUT-OUT; DISCHARGE, DURATION OF.

Cut-off Relay. See 'Automatic Cut-out Relay' under RELAY.

Cut-out.—

['*Cut-outs* or *fuses* are appliances for inserting pieces of an easily fusible metal into the electric circuit, so that in case of a sudden large increase of current this metal melts, and so cuts off the current automatically.' —P. 6 of 3rd ed. of Leaf's 'The Internal Wiring of Buildings'.]

['A device for protecting apparatus from damage by overload. The term *cut-out* comprises all the separate parts which, together with their mountings and base, form the complete device, and the term includes FUSES and CIRCUIT BREAKERS.'—I.E.C.]

See AUTOMATIC CUT-OUT; FUSE; 'Automatic Circuit-breaker' under CIRCUIT BREAKER.

Cut-out, Battery. See BATTERY CUT-OUT.

Cut-out, Discriminating. See 'Reverse-current Circuit Breaker' under CIRCUIT BREAKER.

Cut-out, Double-pole. See DOUBLE-POLE CUT-OUT.

Cut-out, Magnetic. See 'Automatic Circuit Breaker' under CIRCUIT BREAKER.

Cut-out, Single-pole. See SINGLE-POLE CUT-OUT.

Cut-out Relay, Automatic. See RELAY.

Cutting Lines of Magnetic Force.—When a conductor cuts lines of magnetic force, an emf, e, is induced which is proportional to (1) the strength of the field or flux density H, (2) the length of conductor l, or, more precisely, that component of the length which is normal to the flux, and (3) the speed, v, at which the conductor is moving, or, more precisely, that component of the speed which is normal to the flux.

Thus in cgs units,

$$e = \text{H} \times l \times v; \text{ or volts generated } = \frac{\text{lines cut per sec}}{10^8}.$$

When a conductor which is carrying current is in a magnetic field, it tends to move at right angles, both to the direction of flow of the current and of the magnetic flux; that is, it tends to move so as to cut the magnetic flux. The force with which it tends to move is

$$f = \text{H} \times l \times i \text{ dynes},$$

where i is the cgs unit of current; or, if I is the current in amp,

$$f = 1{\cdot}02 \times \text{H} \times l \times \text{I kg}.$$

For direction of forces see FLEMING'S RULE; CORKSCREW RULE; AMPERE'S RULE.

Cycle.—

['*Cycle*, a term not recommended as a synonym for *period* (which see).'—I.E.C.]

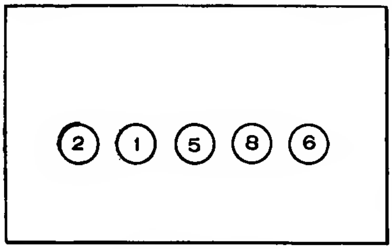
See ALTERNATING CURRENT.

Cycle of Alternation. See ALTERNATING CURRENT.

Cyclic Irregularity.—Owing to the uneven turning effort in steam and gas engines, the speed of revolution varies slightly from time to time during each revolution. As a measure of their regular running, the maximum variation in speed during the revolution is divided by the mean speed. This figure is called the cyclic irregularity, and, for engines driving alternators in parallel, should be at least $\frac{1}{200}$, and preferably less than $\frac{1}{300}$. See CRANK EFFORT DIAGRAM; TORQUE DIAGRAM OF AN ENGINE.

Cyclometer Counter, a train of number-wheels, drums, or disks, gearing together, and driven through a worm or pinion on the meter spindle, so that the numerals on the number-wheels appear in a single row, through slots in the dial face, as shown diagrammatically in the accompanying sketch.

The dial reading gives the energy consumption direct in terms of the unit of electrical energy (*i.e.* the kelvin or kw hr) without the use of a multiplier or constant. A cyclometer counter has the great advantage over the ordinary dial register (see under) that the reading is very simple, and errors cannot be made, provided that two figures

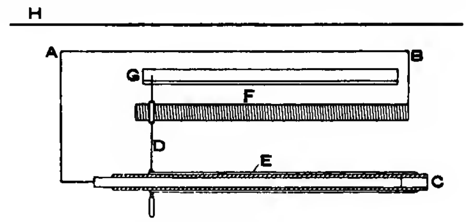


Cyclometer Counter

on the same number-wheel cannot show simultaneously through the dial openings. To prevent the numbers from occupying intermediate positions, giving rise to inaccuracies in the reading, the change from one numeral to the next is made suddenly by means of an intermittent motion of the number-wheel, so that it does not rotate continuously as in the dial register or crawling type of cyclometer counter, which latter should be discarded. This intermittent, or jump, motion is effected in various ways, *e.g.* by means of springs or revolving weights. The first number-wheel revolves continuously, but all the others revolve intermittently, and the first number-wheel usually denotes a decimal place ($\frac{1}{10}$th place) of the kelvin (or BTU), which is used for testing only.

Cymometer, an instrument, designed by Prof. Fleming, for measurement of the natural frequency of oscillatory electric currents. It consists of an air-cored wire coil in series with a condenser, the plates of which are concentric metal tubes.

By sliding the outer tube off the inner, the capacity can be decreased, and the same sliding movement is made to diminish the inductance of the coil in series with it. By the simultaneous change of capacity and inductance the *oscillation constant*, *i.e.* $\sqrt{\text{capacity} \times \text{inductance}}$ can be varied



Cymometer

A, B, Straight wire for induced current. C, E, Tube plates of condenser. D, E, Sliding tube and contact. F, Air-core inductive coil. H, High-frequency circuit.

over a wide range, and this constant is proportional to the frequency to which a circuit will respond. The circuit whose frequency is to be measured is made to induce currents (of the same frequency) in the cymometer circuit, and the adjustment is made until resonance is indicated by the maximum brightness of a vacuum tube placed across the condenser.

The oscillation constant can then be read off on the scale, and the frequency calculated from the formula:

$$\sim = \frac{1}{2\pi \times \text{oscillation constant}}.$$

The cymometer is also used to measure small capacities and inductances. An unknown capacity is placed in series with a simple circuit whose inductance can be calculated; the oscillation constant is determined by the cymometer, and the capacity can then be calculated. See DISCHARGE, OSCILLATORY.

D

D.P. Accumulator. See ACCUMULATOR.

Damped.—

['*Damped*, the motion of a piece of mechanism is said to be damped when any oscillations which may be started rapidly die away. If no oscillations can be produced, it is said to be *aperiodic*.'—I.E.C.]

See also DAMPING; DEAD-BEAT; DISCHARGE, DEAD-BEAT.

Damped Galvanometer. See GALVANOMETER.

Damper, any device introduced into a machine or instrument for the purpose of dissipating energy which would otherwise cause the moving portion of the machine or instrument to oscillate about any given position after the manner of a pendulum. [M. B. F.]

Damping: To Damp, to check, reduce, or eliminate oscillations, *e.g.* to damp vibrations.

To absorb or dissipate the store of energy which causes a system to vibrate or oscillate after the manner of a pendulum; thus, measuring and other instruments are frequently provided with damping devices for the purpose of annulling oscillations of the moving system, thus causing the moving system to assume its final position as rapidly as possible.

Damping devices for instruments may consist of air vanes, or vanes moving through other fluids, such as oil, or they may consist of metallic bodies moving in a magnetic field, so that electric currents are thereby induced in them. In these cases the retarding force is proportional to the velocity, and the rate of dissipation of energy is proportional to the square of the velocity. Anything in the nature of solid friction, however, is inadmissible for the purpose of damping. See DAMPED; DECREMENT, LOGARITHMIC. [M. B. F.]

Damping, Magnetic, in Meters. See METER, RETARDING TORQUE OF MAGNETIC BRAKE.

Damping Coil, a coil introduced into a machine or instrument expressly for the purpose of damping; a coil closed upon itself, and so arranged in relation to the moving system that the oscillations or movements of the latter give rise to electric currents in the closed coil, whereby energy is dissipated. [M. B. F.]

Damping Factor equals the *logarithmic decrement* (see DECREMENT, LOGARITHMIC), divided by π.

Damping Grid, an interconnected system of conducting bars inserted in holes, slots, or otherwise attached to the polar faces of certain classes of dynamo machines, and so arranged that dissipation of energy occurs if the machine is set into the state of oscillation, technically known as hunting, surging, &c. See also AMORTISSEUR. [M. B. F.]

Damping Magnet. See MAGNET, DAMPING.

Damping Magnet in Meters. See METER, RETARDING TORQUE OF MAGNETIC BRAKE.

Damping Ring, a metallic ring introduced for the purpose of checking oscillations. See also DEAD-BEAT OR APERIODIC ELECTRICAL MEASURING INSTRUMENTS; 'Damped Galvanometer', under GALVANOMETER; METER, RETARDING TORQUE OF MAGNETIC BRAKE.

Danger.—

['*Danger* means danger to health or danger to life or limb from shock, burn, or other injury to persons employed, or from fire attendant upon the generation, transformation, distribution, or use of electrical energy.'—From definitions accompanying Home Office, 1908, Regulations for Electricity in Factories and Workshops.]

Daniell Cell. See CELL, DANIELL.

D'Arsonval Ammeter. See AMMETER.

D'Arsonval Galvanometer. See GALVANOMETER.

Dash-pot.—

['*Dash-pot*, an appliance for preventing sudden or oscillatory motion of any portion of an apparatus by the friction of air or of a liquid.'—I.E.C.]

Dash-pot for Electrical Measuring Instruments. See DEAD-BEAT OR APERIODIC ELECTRICAL MEASURING INSTRUMENTS.

Dash-pot of Arc Lamp. See LAMP, ARC.

Dead.—

['*Dead* means at or about zero potential, and disconnected from any live system.'—From definitions accompanying Home Office, 1908, Regulations for Electricity in Factories and Workshops.]

Dead-beat.—

['*Dead-beat.*—An instrument or other mechanism is said to be dead-beat when the oscillatory movement rapidly dies away. To be distinguished from *aperiodic*.'—I.E.C.]

Dead-beat or Aperiodic Electrical Measuring Instruments, instruments in which the motion is damped out to such an extent that the pointer accurately follows all ordinary variations in current. Strictly speaking, instruments should only be described as dead-beat when *critically damped*, *i.e.* when the pointer comes to rest without overshooting the point of equilibrium. If still further damped, such an instrument becomes sluggish; occasionally some sluggishness is an advantage, as it enables a steady reading to be obtained on a rapidly fluctuating load (for example, a gas-engine circuit). *Dash-pots* of various kinds, usually air or oil, are used for this purpose, as also *damping magnets* (see MAGNET, DAMPING), inducing eddy currents.

Dead Coil, (1) a coil on an armature which has become short-circuited. The coil will carry a heavy local current, and will, in a short time, char the insulation, and so ground the armature windings on to the core. Also sometimes used to indicate a coil which has been cut out of the circuit and left open-circuited. (2) In some special windings, a coil is put in place, for the sake of symmetry, which, for electrical reasons, is not required, and which, consequently, is not connected to the rest of the armature winding. Such a coil is sometimes called a *dead coil*, but is more generally known as a *dummy coil*. See also DEAD TURNS.

Dead-man's Handle, a device incorporated with the handle of the master controller of an electric train, such that, if the driver, for any reason, ceases to press on the handle whilst the train is in motion, the electric power is cut off and the brakes are applied, bringing the train to rest. See also CONTROLLER, MASTER.

Dead Segment, a commutator bar which has from any cause or for any reason become disconnected from the armature. If the brush covers more than two segments, satisfactory working may in certain cases be obtained for a time, but the bars on either side will be subjected to extra duty, and will, in time, blacken. If, however, narrower brushes are in use, a violent flash will occur every time the segment passes under a brush, and satisfactory operation will become impossible.

The term *dead segment* has also been employed to denote a segment of a commutator which is not connected directly to the armature winding, but which is connected to the adjacent segment through a small resistance. The object of this is to facilitate commutation, as the current in the coil undergoing commutation is reduced considerably in value by the insertion of this resistance, as it moves out of the field of commutation.

Dead Short Circuit. See CIRCUIT, ELECTRIC.

Dead Turns, turns of wire which are not carrying current; turns on a cc armature which are not connected with the rest of the winding, but make up a dummy coil or *dead coil* (which see).

Dead Wire, (1) wire which is not carrying current; (2) on dynamo-electric machines, wire such, for instance, as that constituting the end connections of an armature winding, which is not cutting lines of magnetic force, and in which no emf is being induced.

Deceleration. See ACCELERATION.

Decimal Candle. See 'Violle Standard of Light' under STANDARD OF LIGHT.

Decimeter, Cubic. See CUBIC DECIMETER.

Declination, Angle of. See ANGLE OF DECLINATION.

Declination, Magnetic. See ANGLE OF DECLINATION.

Declinometer, a magnetic needle mounted to move in a horizontal plane, and on a stand fitted with a telescope or other arrangement of sights, by means of which the angle between the direction of the needle and the astronomical true north may be measured. See DEVIATION.

Decohere, to destroy coherence, *i.e.* to increase the resistance of the imperfect contact of the coherer, which has been reduced by the passage of current. This is usually effected by a mechanical shock. At present the term is chiefly employed in wireless telegraphy. See DETECTOR.

Decoherence. See DECOHERE.

Decomposition, Electrolytic. See ELECTROLYSIS.

Decrement, Logarithmic.—When an oscillatory motion is gradually decreasing in amplitude, on account of loss of energy through radiation or frictional actions, it is said to be *damped*. The damping per half-period is the ratio of the amplitude of the second half-wave to the first, and the Napierian logarithm of this ratio is called the *logarithmic decrement*. See DAMPING FACTOR; DAMPED; DAMPING.

De Faria Valve. See RECTIFIER.

Deflection Wattmeter. See WATTMETER, DEFLECTION.

De Forest System of Wireless Telegraphy. See 'De Forest System' under WIRELESS TELEGRAPHY.

Deformation of Filament. See FILAMENT.

Degradation of Energy. See ENERGY.

De Laval Diverging Nozzle. See NOZZLE.

Deltabeston Magnet Wire, the trade name of a special fireproof magnet wire, the covering of which has an asbestos base.

Delta Connection. See CONNECTIONS, THREE-PHASE.

Delta Grouping. See CONNECTIONS, THREE-PHASE.

Demagnetisation, the weakening of the magnetic field through the presence, on some part of the magnetic circuit, of ats acting in opposition to the main magnetising force, *e.g.* the effect of the armature back ats. See ARMATURE REACTION.

Demagnetising Effect of Armature. See ARMATURE REACTION.

Demagnetising Turns, turns the effect of which is to oppose the main magnetising force, and therefore to weaken the magnetic field; more particularly the back ats of a dynamo armature. See ARMATURE REACTION.

Demerbe Rail, a tramway rail in the form of an inverted trough, the upper surface of which is similar in shape to an ordinary grooved tramway rail. Consecutive rails are joined by internal fishplates, and the whole is bedded in concrete, with which the inside of the trough is completely filled.

Demi-car. See SINGLE-ENDED ELECTRIC TRAMCAR.

Density of Current. See CURRENT DENSITY.

Density Tester, Bismuth Spiral. See TESTER, BISMUTH SPIRAL DENSITY.

Depolarise, to eliminate, by chemical or other means, the counter emf of polarisation (see COUNTER EMF OF POLARISATION). Many methods are employed in practice.

CHEMICAL METHODS.—

1. Oxidation of the hydrogen by potassium bichromate (see 'Bichromate Battery' under BATTERY, PRIMARY), by nitric acid (see 'Grove Battery' and 'Bunsen Battery' under BATTERY, PRIMARY).

2. Substitution of the hydrogen by some other substance which does not give a counter emf of polarisation, *e.g.* in the Daniell cell by replacement of the copper, in copper sulphate, by the hydrogen, the copper being deposited on the positive pole. See CELL, DANIELL.

NON-CHEMICAL METHODS.—

1. Agitation of the liquid or of the positive electrode, in order to prevent the accumulation of hydrogen on the pole.

2. Corrugating or roughening the positive electrode, as in the Smee cell (which see). This causes the gas to form in large bubbles, which rise to the surface more rapidly than the small bubbles which would form on a smooth electrode.

Depolariser, the substance employed in voltaic cells to combine with the hydrogen, which would otherwise be set free at the positive electrode, and cause polarisation.

Depolariser Bag, a cylinder of hemp or other fabric used in place of porous pots in some forms of Leclanché cell (see 'Dry Battery' under BATTERY, PRIMARY), and also as a support for the depolarising mass in some forms of dry battery where the exciting mass is of a thin gelatinous nature.

Depolariser for Primary Cells. See DEPOLARISE.

Deposition of Metals, Electric. See 'Electro-Deposition' under ELECTROMETALLURGY.

Depreciation of Electrical Plant. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Deprez-d'Arsonval Galvanometer.—This term was formerly widely employed to designate the type of galvanometer now more commonly referred to simply as the d'Arsonval galvanometer. See GALVANOMETER.

Depth of Air Gap. See AIR-GAP DEPTH; CLEARANCE.

Derived Circuit, a term occasionally employed to denote a shunt to some portion of a circuit. The portion to which the derived circuit is in shunt usually contains a source of emf. The term is less frequently employed than formerly. Thus field coils of a self-exciting dynamo were formerly frequently designated as constituting the derived circuit.

Derived Unit. See UNIT, DERIVED.

Derrick or Scotch Electric Crane. See CRANE, ELECTRIC.

Design Formulæ (for electrical apparatus), formulæ defining the relations between various dimensions and properties of a dynamo or other apparatus, and substitution in which enables such dimensions to be fixed, or such properties to be predetermined in any given case.

Dessendier's Photometer. See PHOTOMETER, ACTINIC.

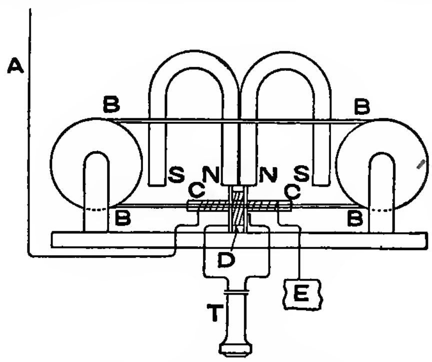
Destructor Station for the Generation of Electricity by Consumption of Refuse. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Detachable Teeth. See TEETH, ARMATURE.

Detector, applied to a variety of devices for indicating the presence of some form of matter or energy. In wireless telegraphy, the part of the receiving apparatus which is sensitive to the hf currents.

WAVE DETECTOR, a mechanism capable of indicating the passage of momentary electric currents, particularly short-lived ac of hf. Wave detectors may, according to their method of action, be classed as follows: (1) *Coherers*, or *imperfect contacts*, resistance changed by current; (2) *electrolytic*, change of back emf, or resistance; (3) *thermometric*, effects of change of temperature, including resistance and thermo-electric emf; (4) *magnetic*, change of magnetisation of iron; (5) *electromagnetic*, inter-action of electromagnetic forces, as in an electrodynamometer; (6) *valves* or *recti-*

fiers, transforming the hf current to a measurable unidirectional current; (7) *silicon detector*; a piece of silicon between metal contacts forms a rectifying detector for hf currents, and may therefore be employed in conjunction with a telephone as receiver in wireless telegraphy and telephony; (8) a *miscellaneous* class as yet unexplained. Examples: (1) Lodge coherer; Marconi filings coherer; (2) Fessenden's barretter; De Forest electrolytic; (3) Duddell's thermo-ammeter; (4) Marconi's and Fessenden's magnetic; (5) Fessenden's heterodyne; (6) Fleming's valve; De Forest's audion. The Marconi magnetic detector is illustrated in the figure.



Marconi's Magnetic Detector

A, Aerial wire. B, B, Iron band round pulleys. S, N, Permanent magnets. C, C, Primary winding on glass table through which the iron band travels. D, Secondary winding. E, Earth-plate. T, Telephone receiver.

AUTO-DECOHERING WAVE DETECTOR, a hf current detector which recovers its sensitive state automatically. The term is applied to coherers which recover their sensitive state after a signal has been indicated, by the action of the constant local-battery pressure. [J. E-M.]

Detector, Earth. See LEAKAGE INDICATOR.

Detector, Magnetic.—1. A rough galvanometer sometimes used for testing purposes, consisting generally of a magnetised needle mounted on a pivot and surrounded by a high-resistance coil so placed as to deflect the needle when the slightest current passes through the coil. In one form this instrument is termed a *linesman's detector*, and is chiefly used to detect continuity in an electrical circuit; consequently it is sometimes spoken of as a *circuit indicator*.

2. A form of induction balance arranged for the purpose of detecting the presence of magnetic substances.

3. A type of wave detector employed by Marconi and others. See 'Wave Detector' under DETECTOR.

Detector Circuit, the local receiving circuit of a wireless-telegraph station, containing the detector, which is actuated by the hf current from the aerial wire, and the telephone and battery which indicate its action. In some cases, such as Marconi's magnetic detector (illustrated at the definition of Detector), a battery is not required. [J. E-M.]

Deterioration of Incandescent Lamps. See LAMP, INCANDESCENT.

Deterioration of Sheet Iron. See AGEING.

Developed Armature-winding Diagram. See WINDING DIAGRAM.

Deviation, the angle which a compass needle pointing to the magnetic north pole makes with a line drawn to the true geographical north pole.

SEMICIRCULAR DEVIATION, an expression used in connection with ships' compasses. The iron of which a ship is made becomes permanently magnetised during construction. This produces a variable deviation between the compass needle and the true north, which passes through a complete cycle whilst the ship is turned round through one complete revolution. The maximum value of the deviation due to this cause is known as the semicircular deviation.

QUADRANTAL DEVIATION.—The iron of a ship, besides becoming permanently magnetised during construction, becomes temporarily magnetised by induction from the earth's magnetism, to an extent which varies with the different angles at which the ship is placed with the direction of the earth's magnetism. This temporary magnetism produces a variable deviation between the compass needle and the true north, which passes through a complete cycle while the ship is being swung through half of a complete revolution. The maximum deviation of the compass due to this cause is known as the *quadrantal deviation*.

Diagram, Circle. See CIRCLE DIAGRAM; DISPERSION, MAGNETIC.

Diagram, Winding. See WINDING DIAGRAM.

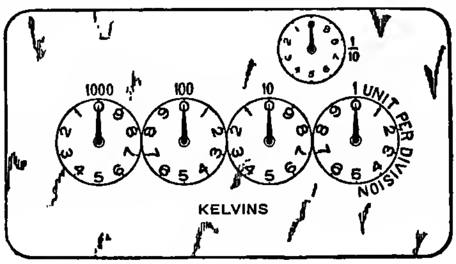
Dial, Plug. See PLUG DIAL.

Dial, Sliding Contact. See SLIDING CONTACT DIAL.

Dial, Wheatstone's Bridge. See BRIDGES.

Dial Instrument, Illuminated-, an instrument having the scale illuminated by self-contained lamps, the dial being usually transparent, and having one or more lamps fixed behind it. Sector, or more rarely, edgewise instruments (see INSTRUMENT, SWITCHBOARD MEASURING) are the commonest forms to which the plan of illuminating the dial is applied.

Dial Register, a train of wheels and pinions gearing with one another and actuating index hands over graduated circles



Dial Register

on the dial face. In the ordinary type adjacent index hands revolve in opposite directions, the figures on the dial circles being correspondingly marked, as will be seen in the accompanying illustration. The dial registers the energy-consumption direct, in terms of the unit of electrical energy (kelvin, kw hr, or BTU). Some care is necessary in reading the dials, since very often an index hand gets slightly displaced, giving rise to an error in the reading. The next hand on the right of the faulty one will act as a guide to the correct figure. See CYCLOMETER COUNTER.

Dial Telegraph. See TELEGRAPH, DIAL.

Diamagnetic.—Substances whose magnetic permeability is less than that of air are termed *diamagnetic*. They are repelled from a magnetic field. Bismuth is an example of a diamagnetic substance. The extent to which the permeability of diamagnetic substances is less than that of air is so slight that the phenomenon of diamagnetism is of but very little practical importance. The lines of force in a diamagnetic field are less dense than in the air surrounding it, and *poles, i.e.* convergence or divergence of lines, appear on the body against the inducing field. (Ref. 'Electrical Researches', Faraday; Lord Kelvin's 'Papers on Electrostatics and Magnetism'.)

Diamagnetism, discovered by Faraday, and exhaustively investigated by Tyndall. See DIAMAGNETIC.

Diameter at Air Gap. See AIR-GAP DIAMETER.

Diameter of Commutation, that diameter of the commutator in a bipolar machine at the extremities of which the brushes are situated. The conception is extended to multipolar machines, where the diameter of commutation is replaced by a number of radial lines, one for each pole. See ARMATURE REACTION; COMMUTATION.

Diamond-shaped Form-wound Coil. See COIL, FORM-WOUND.

Diapason, Electric, an electric vibrator for producing sound. Instruments of this type are used occasionally on telephone lines instead of call bells; also as motor horns.

Diaphragm (1) a thin flexible plate. (2) 'The porous partition or wall separating the anode and cathode compartments of an electrolytic cell' (Kershaw's 'Electrometallurgy'). See 'Electrolytic Cell' under ELECTROLYSIS.

Diatrine, the trade name of an insulating compound used for the impregnation of the paper in paper-insulated cables, and also as an insulating compound for filling joint boxes. The compound is made, by a secret process, from certain heavy insulating oils. The manufacturers claim that it has high dielectric strength and insulation resistance, combined with low specific inductive capacity. The consistency of the compound, when cool, is of a semi-solid nature, and it does not run or become brittle, within the limits of temperature met with in electrical working.

Diatto Surface-contact System. See SURFACE-CONTACT SYSTEM.

Dick Automatic Potential (or **Voltage) Regulator.** See REGULATOR, POTENTIAL.

Die; Dies.—

COMPOUND DIE, an expensive type of die for punching out, at a single stroke, an entire armature disk, together with the slots at the periphery, or else a segment of such a disk. The construction of such a die involves great skill and care, and, owing to its expense, is rarely justified except where a very large number of identical core plates are required. A compound die for a rather small armature disk is shown in fig. 1.

BLANKING DIE, a die which stamps a complete segment of an armature core without the teeth and slots, these being afterwards formed in an index press.

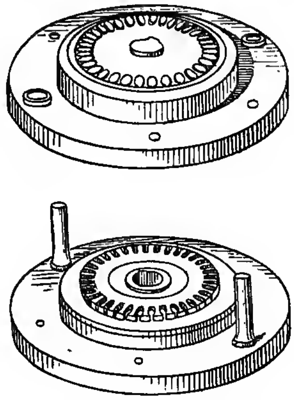


Fig. 1.—Compound Die

NOTCHING DIE, an index-press die which notches the slots singly in a segment which has been previously blanked. A notching die is shown in fig. 2. A notching die is sometimes termed a *finger die* or *index press*.

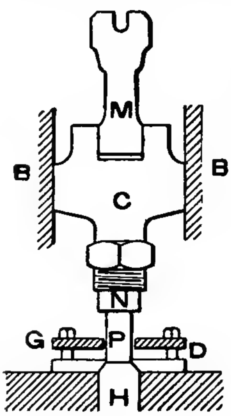


Fig. 2.—Notching Die

M, Connecting-rod for driving. B, B, Guides of slide-block C. N, Punch-holder. P, Punch. D, Die. G, Guide of punch. H, Aperture in bed of punching machine.

T-DIE, a notching die which not only forms the slot, but that portion of the armature face on either side. In this way a square sheet may be formed into a finished core plate by one central blanking die and a T notching die, which will punch the slots, and also at the same time remove the corner pieces step by step. A T-die is illustrated in fig. 3.

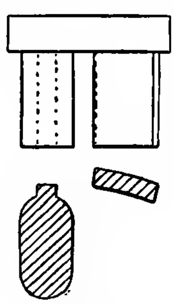


Fig. 3.—T-die

FRENCH-TYPE DIE.—This type, the distinguishing principle of which is incorporated in the apparatus employed for illustrating the *notching die* (see the illustration above, fig. 2), is characterised by the guiding of a punch P by means of the guide G. The plates must be inserted between the lower surface of the guide G and the upper surface of the die D. This type affords a very exact guidance to the punch P, right close down to the surface to be punched.

GERMAN-TYPE DIE.—The principle is indicated in fig. 4. The punch is mounted firmly on a solid piece, and can thus only penetrate to a short distance below the upper surface of the die. (Ref. 'Armature Construction', Hobart and Ellis).

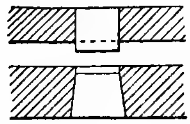


Fig. 4.—German-type Die

Dielectric, any substance in which electrical actions are propagated after the manner of mechanical stresses in solids. Thus the continuous application of a steady electric force to a dielectric does not produce a continuous transmission of energy, but merely transmits, at the commencement of the application of the force, a finite quantity of energy, whose amount depends on the material and dimensions of the dielectric and on the force applied. Since the maximum electrical pressure which can be applied is finite, it is clear that to keep up a more or less continuous transmission of energy through a dielectric, it is necessary that the force applied should be alternating in direction, or at least varying. If the force be alternating, the rate of transmission of energy will increase, other things being equal, with the number of alternations per sec. On the *electronic* or *discrete-particle* theory of electricity, which is now generally accepted, a dielectric is a material through which the electrons do not diffuse freely, as they do in conductors. [J. E-M.]

In the 1907 Wiring Rules of the Institution of Electrical Engineers, which apply to the supply of electricity at 1 pr not exceeding 250 volts, a dielectric is defined as follows:—

'A dielectric is any material which, by its nature or by the method of its application to a conductor, permanently offers high resistance to the passage of current and of disruptive discharge through itself.'

[' *Dielectric*, any material which offers high resistance to the passage of an electric current.'—I.E.C.]

Dielectric Constant (or Specific Inductive Capacity).—Faraday discovered that different substances have different powers of carrying lines of electric force. Thus the charge of two conductors having a given difference of potential between them depends on the medium between them, as well as on their size, shape, and potential. The number indicating the magnitude of this property of the medium is called its *dielectric constant.* The dielectric constant of air, which is nearly the same as that of a vacuum, is taken as unity. In terms of this unit the following are some typical values of the dielectric constant: Water 80, glass 6 to 10, mica 6·7, gutta percha 3, indiarubber 2·5, paraffin wax 2, ebonite 2·5, castor oil 4·8. See CAPACITY, ELECTROSTATIC; CABLE, GRADED. [J. E-M.]

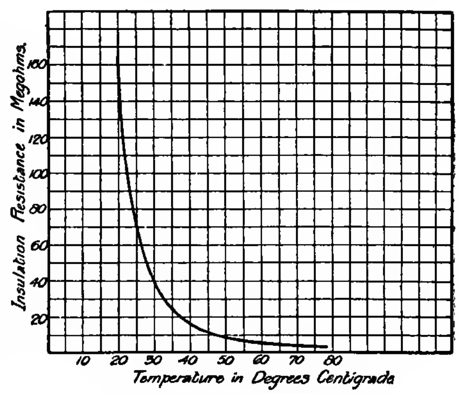
Dielectric Fatigue.—Certain solid dielectrics appear to lose their power of resistance to disruption by electric force after the force has been applied for a considerable time. This may be due to molecular changes, or, in the case of a non-homogeneous substance, such as imperfect rubber, to the collection of water, oil, or other substance of high dielectric constant, in the lines of greatest stress. (Ref. O'Gorman, Journ. I.E.E., Nov., 1907.) [J. E-M.]

Dielectric Hysteresis.—Any alteration of the electric stress in a dielectric is usually attended by a certain waste of energy, *i.e.* some heat is produced. If the applied electric force and the electric induction caused by it be represented in a diagram, a curve somewhat similar to the magnetic hysteresis curve is obtained, whose area indicates the work done in forcing the dielectric through the cycle. If subjected to sufficiently high alternating pressures, a dielectric may become hot. Thus in some tests carried out by Siemens, an alternating pressure of 50,000 volts applied to two sides of a glass plate about 5 mm thick caused it to become so hot in about half a minute that a small hole was melted through it. See INSULATING MATERIALS, ENERGY LOSSES IN. [J. E-M.]

Dielectric Hysteretic Lag.—Energy is required to force a dielectric through any cyclic change of electric stress. As in magnetism, this energy may be represented by the area of the closed curve showing the relation of stress to strain throughout the cycle. The strain lags behind the stress. See DIELECTRIC HYSTERESIS. [J. E-M.]

Dielectric Polarisation, a term indicating the amount of electrical stress in a dielectric. (Ref. 'Electricity and Magnetism', Clerk-Maxwell.) See also POLARISATION OF THE MEDIUM.

Dielectric Resistance.—All dielectrics (or insulators) have a certain amount of conductivity, and hence also resistance, for no substance is known which acts as a perfect insulator. The ohmic resistance of any insulating body is called its *dielectric resistance* or *insulation resistance.* It is generally measured in megohms. This quantity should be carefully distinguished from *dielectric strength,* to which it does not appear to bear any simple relation. The resistance of practically all dielectrics *decreases* with rise of temperature, while that of metallic bodies *increases* under the same conditions. In the fig. is given a



Dielectric Resistance

curve showing the rapidly decreasing resistance of the dielectric employed in insulating the primary of a transformer from the secondary as the temperature increases. See also INSULATION RESISTANCE. [J. S. S. C.]

Dielectric Strain.—This term is applied to the state of stress or strain to which any insulating material is subject when it separates two bodies at different potentials. The stress increases with increase of pd, and may eventually result in breakdown of the insulating body (see 'Insulation Breakdown' under INSULATION). It is quite distinct from the slight conduction or leakage which takes place through all insulating bodies under similar conditions, and which is the other main cause of breakdown. See DIELECTRIC STRESS. [J. S. S. C.]

Dielectric Strength, the capacity of an insulating material to resist insulation breakdown. As here defined, it is not a constant for any one material, but depends on a number of factors. Even if all other determining influences are kept rigorously constant, it is not usually independent of the thickness of the material tested. It is therefore an exceedingly difficult quantity to handle with precision. Under ordinary conditions of test, the matter is further complicated by the effect of dielectric resistance and of leakage currents. For a true measure of dielectric strength, we should, therefore, take the least pressure which will cause *instantaneous* breakdown, but here we are confronted with the great difficulty of deciding whether a given breakdown is really instantaneous.

Let us first give our attention to the question of the strength of dielectrics to withstand actual dielectric stress. The physical quantity that determines this stress is the rate of fall of potential through the dielectric. This rate of fall will be controlled by the distribution of electrostatic flux, which depends on (1) the pd applied, (2) the shape of the electrodes, and (3) the relation between the specific inductive capacity (dielectric constant) of the material under test and that of the surrounding medium. Any sharp points, or places of small radius of curvature on the electrodes, will result in a concentration of the rate of fall of potential, and therefore in a lower breakdown pressure. This explains the well-known *point effect* (which see). If the surrounding medium has a relatively high specific inductive capacity, the breakdown pressure will be lower than otherwise. This may explain the apparently poor dielectric strengths found for mica and some other materials when tested under oil.

THE DIELECTRIC STRENGTH OF GASES is measured by their *resistance to sparking*, usually between opposed sharp needle points. Besides the influence of the shape of the electrodes, the following are found to affect the results: (1) the pressure and temperature of the gas, (2) the presence of neighbouring conductors, (3) the presence of extraneous ionisation. Except at very l pr, the spark length in a gas runs up with the density in accordance with a straight-line law. The effect of temperature is apparently only that of changing the density. The presence of neighbouring conductors alters the distribution of electrostatic flux. Extraneous ionisation facilitates the discharge. For engineers, the *dielectric strength of air* is that of most importance amongst gases. All that has been said for gases generally is applicable here. Ionisation may be caused by sunlight, or may come from previous or neighbouring discharges, and produces effects of greater magnitude than is commonly supposed. Moisture and other impurities lower the effective dieletric strength of air. For an interesting account of how the influence of the shape of the electrodes may be mathematically eliminated, see a paper by Russell in vol. xx of the Proc. of the Physical Society. See COMPRESSED GAS AS AN INSULATOR.

THE DIELECTRIC STRENGTH OF LIQUID INSULATING MATERIALS is affected by much the same causes as that of gases, but extraneous ionisation is here of relatively little practical importance. For commercial purposes, the presence of moisture and of suspended impurities is of the greatest moment. Any fibres or fluff floating in the liquid, will line up between the conductors when a pd is applied. This, of course, results in distortion of the electrostatic field, invariably in the direction of facilitating breakdown.

THE DIELECTRIC STRENGTH OF SOLIDS is subject to less disturbing influences than that of fluids of either kind. Moisture is the worst enemy of high insulating qualities. The dielectric strength of solids is generally measured by testing the material, in the form of a sheet or slab, between disk-electrodes with well-rounded edges, pressed together with a constant force. See 'Insulation Resistance', 'Insulation Breakdown' under INSULATION; SPARKING DISTANCE; DIELECTRIC. (Ref. 'Insulation of Electric Machines', Turner and Hobart; 'Conduction of Electricity Through Gases', J. J. Thomson.)

[J. S. S. C.]

[Paragraph 214 of the 1907 Standardisation Rules of the A.I.E.E. defines the dielectric strength of an insulating wall, coating, cover, or path, as a quantity which is measured by the electrical pressure which must be applied to it, in order to effect a disruptive discharge through it. This definition is followed by a long discussion of the conditions under which the dielectric strength of various materials and types of apparatus should be tested. (Proc.A.I.E.E. for July, 1907, pp. 1001 to 1095.)]

Dielectric Stress.—This term is usually employed as synonymous with *dielectric strain.* Of course, strictly, the strain should mean the effect of the stress in producing physical changes in the dielectric. See DIELECTRIC STRAIN.

Diesel Engine, an oil engine of very high thermal efficiency. The thermal efficiency, referred to the indicated hp, reaches 40 per cent. A kelvin (kw hr) is obtained at a consumption of from 0·32 to 0·36 kg of crude oil. The engine is very well suited for driving electric generators, for which purpose it is extensively used. The operation consists in injecting oil, sprayed by compressed air, into the engine cylinder, in which air has been compressed to a temperature (about 550° C.) high enough to ensure the automatic ignition and complete combustion at constant pressure of the oil as it enters. The Diesel engine is made in sizes up to 800 hp on the "four-stroke" or Otto cycle, and also up to much larger powers on the "two-stroke" cycle. High-speed 2-stroke marine reversing engines from 100 hp at 320 rpm are now also made, as well as larger slow-speed marine engines developing 1000 bhp. The largest engine now under construction is for a capacity of 10,000 hp. The cost of Diesel engines per kw varies from about £18 in the smaller sizes to £12 in the largest.

Differential Booster. See BOOSTER, REVERSIBLE.

Differential Electromagnet. See ELECTROMAGNET, DIFFERENTIAL.

Differential Galvanometer. See GALVANOMETER.

Differential Relay. See RELAY.

Differential Winding. See WINDING, DIFFERENTIAL.

Differentially-wound Arc Lamp. See LAMP, ARC.

Differentially-wound Motor. See COMPOUND-WOUND MOTOR.

Diffused Reflection. See REFLECTION, REGULAR AND DIFFUSED.

Dip, Magnetic.—In order to ascertain the exact direction of the earth's magnetic field, it is necessary to know the angle between the lines of force and the horizontal plane, as well as their declination (which see) from true N and S. If an unmagnetised needle is carefully balanced on knife edges about its centre of gravity, and afterwards magnetised, it will, if placed magnetically N and S, indicate, by its angle with the horizontal, the dip of the earth's field at the point of observation.

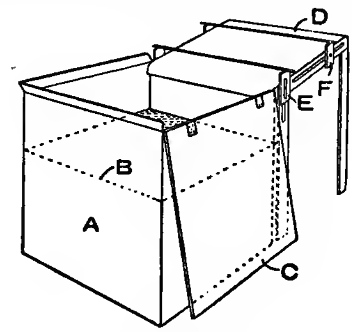
The needle is mounted in front of a vertical scale in order that the dip may be easily read.

Diphase, synonymous with *two-phase.* See 'Two-phase Current' under ALTERNATING CURRENT; ALTERNATING-CURRENT SYSTEM; TWO-PHASE SYSTEM.

Diplex Telegraphy. See 'Multiplex Telegraphy' under TELEGRAPH SYSTEMS.

Dipping Needle. See DIP, MAGNETIC.

Dipping Tank for Armature and Field Coils.—This should be a heavy galvanised-iron tank of convenient shape and dimensions. It should be provided with a tight-fitting cover, capable of being speedily lowered. A dripping pan and racks should be erected at one end to catch the varnish from the dipped coils, and drain it back into the tank. If the tank be of large dimensions, it should be fitted with an outlet at the bottom, so that the varnish may be occasionally



Dipping Tank

A, Dipping tank. B, Varnish level. C, Hinged lid. D, Draining rack with supports E and F, which are adjustable vertically and horizontally respectively.

drawn off, and the tank cleaned. The loss by evaporation may be reduced by maintaining the level of the varnish at some little distance from the brim of the tank. [H. D. S.]

Direct Current. See the preferable term, *continuous current*, the abbreviation of which is CC. Kapp and Thompson, in their various treatises, both employ the term *continuous current* instead of the term *direct current.*

Direct Induced Current. See CURRENT INDUCTION.

Direct-reading Galvanometer. See GALVANOMETER.

Directed Wireless Telegraphy. See WIRELESS TELEGRAPHY, DIRECTED.

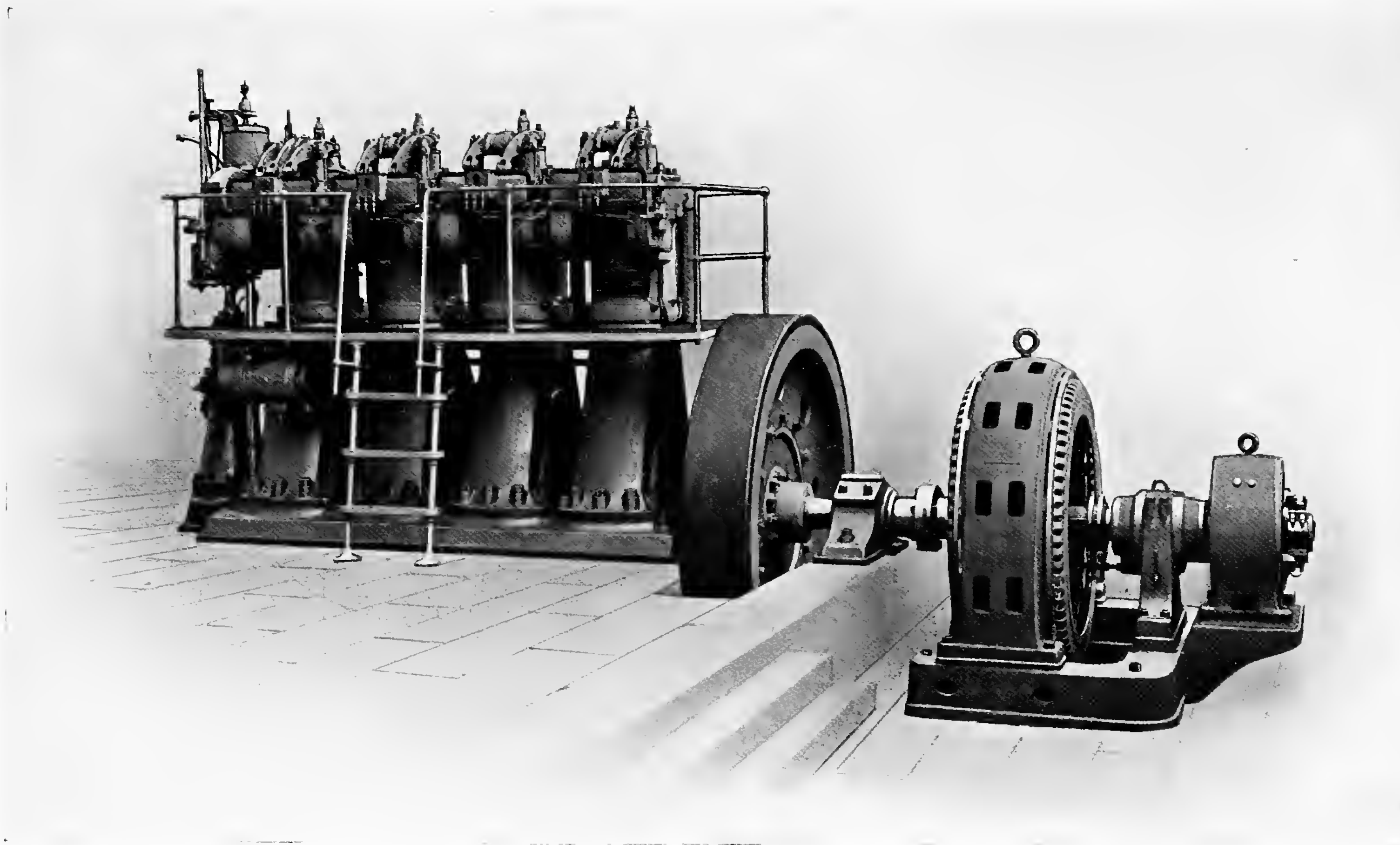
Directing Magnet. See MAGNET, CONTROLLING.

Direction of Electric Current. See CURRENT, DIRECTION OF; CORKSCREW RULE; FLEMING'S RULE; AMPERE'S RULE.

Discharge, Atmospheric. See ATMOSPHERIC ELECTRICITY.

Discharge, Conductive, discharge of electricity along or through a conductor, as opposed to disruptive and convective discharges. On the particle theory, it is due to migration of negatively charged particles through the conductor. [J. E-M.]

Discharge, Convective, discharge of electricity by the motion of charged particles, usually applied to particles of micro-



200-BHP MIRRLEES-DIESEL OIL ENGINE DRIVING AN ALTERNATOR
(Mirrlees, Bickerton, & Day, Ltd., Stockport)

[*To face p. 166.*

scopic but visible dimensions, though occasionally applied to charged gaseous molecules. [J. E-M.]

Discharge, Dead-beat, an electric current which dies out without oscillating, *i.e.* is undirectional. The condition for this type of discharge (if from a condenser) is that the inductance of the circuit shall be less than a quarter of the product of the square of the resistance into the capacity, *i.e.* $L < \frac{R^2C}{4}$. See DISCHARGE, OSCILLATORY. [J. E-M.]

Discharge, Disruptive. — Exceedingly small currents of electricity may flow through the mass of insulating materials without occasioning any permanent change in the materials; but if the current is sufficiently increased by the application of the necessary high electric pressure, the material is mechanically injured, and when this occurrence is accompanied with an abrupt breakdown of the insulation, a disruptive discharge is said to have occurred. In solids the damage is permanent, but in gases and, under certain conditions, in liquids the puncture is self-healing. See also 'Insulation Breakdown' under INSULATION; DIELECTRIC STRENGTH.

Discharge, Duration of. — It is unwise to take a very small discharge from an accumulator for an excessive number of hours without recharging, as the accumulator would be standing for a prolonged period in a partially discharged condition, with probably deleterious effects. No hard-and-fast rule can, however, be laid down on this point. The drop in pressure allowable with various rates of discharge varies with different types, and is fixed by the manufacturers. In some cases the same final pressure is fixed for all rates from 1-hr to 10-hr discharges, and in others the higher the rate of discharge the lower the final pressure allowed. See CUT-OFF POINTS IN DISCHARGE; ACCUMULATOR; EDISON'S NICKEL-STEEL ACCUMULATOR. [F. C.]

Discharge, Electric, a general term covering almost any movement of electricity. It is, however, usually applied to an electrical change in which electrical energy is converted into heat, and is more particularly applied to electric currents, whether temporary or continued, through gases, though it should properly be limited to the *temporary* current caused by the passage of a finite charge of electricity from the conductor, which thus becomes *discharged.* The idea of passage from one conducting medium to another, is often associated with this term, *e.g.* brush discharge, spark discharge, &c. Lichtenberg found that the positive and negative discharges from metal points on to a glass plate produced electrified patterns of quite different character on its surfaces, and Faraday showed that the brush discharges in air exhibit similar differences. These observations indicate an essential physical difference between positive and negative electricity. [J. E-M.]

Discharge, Impulsive, sudden discharge from a conductor. The term is usually applied to a discharge caused by a sudden alteration of electric stress owing to actions in neighbouring conductors, and not by slow attainment of sparking pressure in the conductor itself.

Discharge, Lateral, sparking or brush discharge from the sides of a wire or other conductor, frequently due to the existence of stationary vibrations having potential nodes and loops, owing to the reflection of the current-wave from a dead end or from an inductance (choking) coil.

Discharge, Oscillatory. — Under certain conditions the discharge of a quantity of electricity is unidirectional, under other conditions oscillatory. This was first shown mathematically by Thomson (Lord Kelvin), who gave the following criteria: If L, C, and R be the inductance, capacity, and resistance of the system of conductors, the discharge will be unidirectional if $L < \frac{R^2C}{4}$, and oscillatory if $L > \frac{R^2C}{4}$. Oscillations of this type, having frequencies ranging from less than one up to some hundreds of millions per sec, have been obtained by the use of capacities and inductances of suitable dimensions. The simplest method of obtaining them is by including a spark-gap in the circuit, and raising the pressure until the discharge takes place across the gap. This type of discharge is always *damped*, *i.e.* it dies out gradually. See DISCHARGE, DEAD-BEAT. [J. E-M.]

Discharge, Silent, the quiet leakage of ht electricity into the atmosphere. This is much accelerated by the action of ultra-violet light, radium rays, and similar motions of very hf, or of infinitesimally small particles. [J. E-M.]

Discharger, an arrangement of a pair of insulated electrodes with polished metal ends, usually rounded and occasionally provided with a micrometer screw, between which a spark discharge takes place. See SPARK-GAP.

Discharger (in Blasting), a capsule in which a fine platinum wire is stretched between electrodes, which is used in firing blasting charges or mines, through heating the wire by a current. Many other types of discharger exist, the general idea being that of an instrument used in the conversion of static energy or potential energy into kinetic energy.

Disconnecting Switches. See CIRCUIT-OPENING DEVICES; SWITCH.

Discrete-particle Theory of Electricity. See DIELECTRIC.

Discriminating Cut-out. See 'Reverse-current Circuit Breaker' under CIRCUIT BREAKER.

Discriminating Relay. See RELAY.

Discum Varnish, the trade name for a core-plate varnish. It is not suitable for oil-cooled apparatus. See also CORE-PLATE VARNISHES.

Disintegration of Accumulator Plates. See ACCUMULATOR PLATES.

Disintegration of Filament. See FILAMENT.

Disk, Arago. See ARAGO'S DISK.

Disk, Core. See CORE DISKS.

Disk, Sector. See TALBOT DISK.

Disk, Talbot. See TALBOT DISK.

Disk Armature. See ARMATURE.

Disk Brake, Electromagnetic. See BRAKES.

Disk Coal-cutter, Electric. See ELECTRIC COAL-CUTTER.

Dispersion, Magnetic, magnetic leakage. In practice the term is used almost exclusively in the case of alternating-current motors, and means that portion of the magnetic flux which is not linked with both windings.

DISPERSION COEFFICIENT, more recently termed *circle coefficient,* a very useful factor in the application of the circle diagram of induction motors; it is usually expressed by the symbol σ, and is strictly defined by the equation $\sigma = \frac{L_1L_2 - M^2}{M^2}$, where L_1 and L_2 are the coefficients of self induction of the primary and secondary windings respectively, and M the coefficient of mutual induction. If I_1 represents the stand-still current, and I_2 the no-load current, then, approximately, $\sigma = \frac{I_2}{I_1 - I_2}$; this is the simplest way of determining σ experimentally. The maximum power factor is $\frac{1}{1+2\sigma}$. Other important properties of the motor may easily be deduced from the value of σ. Thus the breakdown factor is approximately equal to $\frac{\gamma}{2\sigma}$, where γ is the ratio of the no-load current to the current at rated load.

[*Note.*—Some writers define σ by the equation $\sigma = 1 - \frac{M^2}{L_1L_2}$; it is then the ratio of the stand-still to the no-load current; the necessary modifications in the equations given above can be very easily made.]

DISPERSION OF THE STATOR, magnetic flux including the stator winding only.

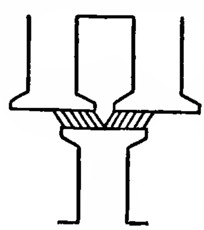
DISPERSION OF THE ROTOR, magnetic flux including the rotor winding only.

The dispersion of a motor can, instead of being considered as stator dispersion and rotor dispersion as defined above, be considered as made up of components according to the path of the leakage flux, thus:

MAIN DISPERSION OR PERIPHERAL DISPERSION is dispersion along the air gap around the periphery of the rotor.

FLANK DISPERSION is the dispersion around those portions of the windings at the ends of the stator or rotor which are not embedded in the iron core.

ZIGZAG DISPERSION.—When the rotor is in such a position that a tooth of one member is opposite a slot of the other member, there is a leakage from the tooth on either side of that slot to the top of the opposite tooth; this leakage travels across the air gap in a zigzag path (see fig.), and is called the *zigzag dispersion* or the *zigzag component of the dispersion.* The coefficient of zigzag dispersion has also been called the *winding coefficient.* (Ref. Journ.I.E.E., vol. xxxiii, 1904, p. 239.) See also BEHREND'S FORMULA.



Zigzag Dispersion

In addition to the peripheral dispersion, the flank dispersion, and the zigzag dispersion, Prof. C. A. Adams, at p. 707 of vol. i of 'Trans. of the International Congress' at St. Louis (1904), first called attention to a fourth component which may be termed the *belt dispersion.* This component is only present in slip-ring motors, and does not exist in squirrel-cage motors. The belt dispersion is much greater in quarter-phase than in three-phase induction motors. The belt dispersion occurs when the primary phase-belt bridges the joint between two secondary phase-belts. (See also Hellmund in 'Electrical World' for March 31, 1906, p. 666, and for Sept. 26, 1908, p. 672.)

Practical methods of estimating the dispersion coefficient (which has recently been termed the *circle coefficient*) of an induction motor, are given by Hobart in chap. xxi of the 2nd ed. (1910) of 'Electric Motors'. See CIRCLE DIAGRAM. [W. B. H.]

Dispersion Coefficient. See DISPERSION, MAGNETIC.

Dispersion Photometer. See PHOTOMETER, DISPERSION.

Displacement, Electric.—When current flows in a conductor, a static charge is set up on its surface. When the current in the conductor rises and falls, the static charge rises and falls in unison with it, so that there is a flow of current from the conductor into the dielectric and vice versa. This current is known as a *displacement current*, and its phase is 90° ahead of the current in the conductor, which latter is known as the *conduction current*. These displacement currents, while they last, set up just such magnetic fields as would be set up by conduction currents. See CURRENT, DISPLACEMENT.

Displacement Current. See CURRENT, DISPLACEMENT.

Displacement of Brushes, the small amount of movement of the brushes of a cc machine around the commutator in order to obtain a more perfect commutation on load. See 'Angle of Lead of Brushes' under ANGLE OF LEAD.

Disruptive Discharge. See DISCHARGE, DISRUPTIVE; 'Insulation Breakdown' under INSULATION.

Disruptive Strength. See DIELECTRIC STRENGTH.

Disruptive Voltage (Disruptive Pressure, Disruptive Potential, Disruptive Tension), the pressure which will just puncture a given piece of insulating material. The effective alternating pressure which will break down a given sample is lower than the pressure of continuous electricity required to produce the same effect. See 'Insulation Breakdown' under INSULATION; DIELECTRIC STRENGTH.

Dissonance, Electric.—When two ac which have frequencies not related to one another, are superposed, then, by the harmonic law, the result is a series of beat vibrations. The frequency of the beats is much lower than the frequency of either of the currents. The wave-form or cycle is thus not repeated every period of the lower vibration, or even in a simple multiple of the latter, as is the case when consonant vibrations or harmonics are superposed. [J. E-M.]

Distance Piece, anything which keeps two parts of a machine securely in place and at a certain distance apart. The term is used more especially in connection with the spacing pieces in the ducts of armature cores, which keep the spaces clear for the circulation of air, and which should preferably be called *ventilating distance pieces*. See also DUCT, VENTILATING; VENTILATION OF ELECTRICAL MACHINERY.

Distant-control of Motor. See REMOTE-CONTROL SYSTEM.

Distilled Water, Conductivity of.—Pure water is remarkable in having a very high specific resistance. Ayrton and Perry give it as $9{\cdot}1 \times 10^6$ ohms per cu cm at 4° C. The resistance decreases as the temperature rises. The conductivity of ordinary tap-water is many times greater than that of pure water, while the addition of any soluble salt produces a further large increase of conductivity. [J. S. S. C.]

Distilled Water for Accumulators.—It is preferable that only water obtained from a suitable distilling apparatus should be used for making good the evaporation from accumulators, as water which may be quite satisfactory for drinking purposes often contains matter injurious to accumulators.

Distilling Apparatus, a method of condensing steam for obtaining perfectly pure water for making good the evaporation from the electrolyte in accumulators.

Distorted Wave Form. See WAVE FORM.

Distortion of Magnet Field. See ARMATURE REACTION.

Distributed Winding. See WINDING, DISTRIBUTED.

Distributing Board.—

['*Distributing Board,* a board carrying bus-bars, used for connecting a number of circuits to a pair of mains. Sometimes called a *distribution board.*'—I.E.C.]

Distributing Box. See BOX, DISTRIBUTING.

Distributing Mains, cables to which

the service mains of individual consumers are connected. See also DISTRIBUTOR.

[‘*Distributing Mains*, the conductors which intervene between the feeders and the service lines, and which are collectively called *distributing network*, or *l pr network*, or the *network*.’—I.E.C.]

Distributing Switch. See SWITCH, DISTRIBUTING.

Distributing System, the distributing mains, together with their ducts, manholes, joint boxes, and everything relating to them. See DISTRIBUTING MAINS; DISTRIBUTOR.

Distribution-board System of Wiring. See WIRING SYSTEMS.

Distribution Centre. See CENTRE OF DISTRIBUTION.

Distribution of Electric Energy.—The distribution of electric energy over large areas is usually accomplished in two stages. Firstly, the electric current at a h pr is led from the central generating station by insulated cables usually laid underground (but occasionally carried overhead on poles), to substations containing converting or transforming machinery, and the current is then led by other insulated cables to the houses, factories, or other premises where it is to be used for lighting, power, or other purposes. See also CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Distribution Factor, a factor introduced into alternator calculations to allow for the different phases of the emf induced in the various conductors, in the case of a distributed winding. Also known as *spread factor* (which see).

Distribution of Windings, the arrangement (more particularly as regards the distribution in few or many slots) of those conductors in a generator or motor which are linked with alternating magnetic fluxes.

Distributor, a cable running from the end of a feeder cable for the purpose of supplying current to service cables, which are connected to it where desired. A distributor generally takes the form of a cable running under the pavement at the side of a street, and short service cables run from it to the premises of each consumer.

The term *distributor* is also sometimes applied to a special terminal device so arranged that a number of cables may be neatly interconnected at a single point, as, for instance, in a manhole or junction box, and that any cable may be easily disconnected without disturbing the other cables. (Ref. ‘Central Electric Stations’, C. H. Wordingham; ‘Central Station Electricity Supply’, Gay and Yeaman.) [F.W.]

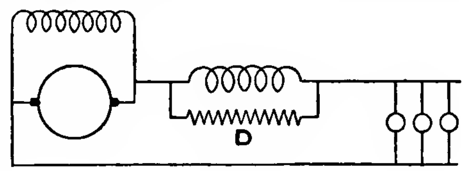
Ditton, the moving, soft-iron tongue of a relay (which see).

Diurnal Load Factor. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Diverging Nozzle. See NOZZLE.

Diversity Factor. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Diverter, a conductor of suitable resistance placed in shunt to a coil for the purpose



Diverter

of diverting a portion of the current from the coil. As employed in parallel with the series field-winding of a dynamo, the diverter is shown diagrammatically at D in the accompanying illustration.

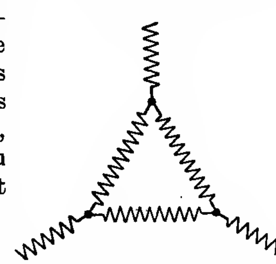
In such a case the resistance of the diverter is sometimes made adjustable, thus permitting of controlling the amount of compounding provided by the series winding. See also SHUNT.

Dividing Box. See BOX, DIVIDING.

Divisibility of Armature. See ARMATURE, DIVISIBILITY OF.

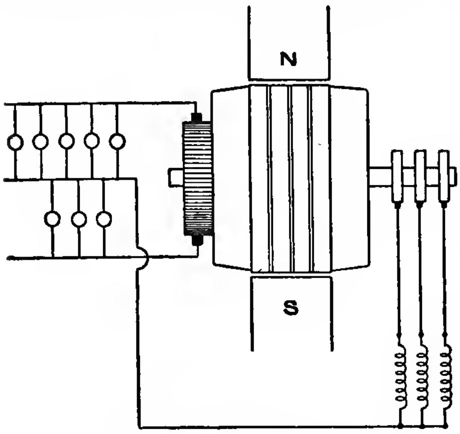
Dm, the preferable abbreviation for *decimeter*.

Dobrowolski Δ-Y Connection for Induction Motors.—In some of Dobrowolski's earlier induction motors there were six windings interconnected, as shown in the fig., where it is seen that there are but three terminals. This is termed *Dobrowolski's* Δ-Y *connection for induction motors*.



Dobrowolski Δ-Y Connection of Induction Motors

Dobrowolski Three-wire Dynamo, a cc generator designed for operating a three-wire system of distribution without a balancer. The armature is provided with insulated slip rings connected with suitable points in the armature winding, and (by means of brushes) with choking coils meeting at a common point, to which the neutral wire of the system is connected, while the main terminals are connected with the outers. The machine is capable of feeding unbalanced loads without serious disturbance of the pressure on



Dobrowolski Three-wire Dynamo

either side of the system. The arrangement with three slip rings is shown diagrammatically in the fig. It is not essential that there should be *three* slip rings; *two* are sometimes employed. See 'Three-wire Compensator' under COMPENSATOR.

Dolezalek Quadrant Electrometer. See ELECTROMETER.

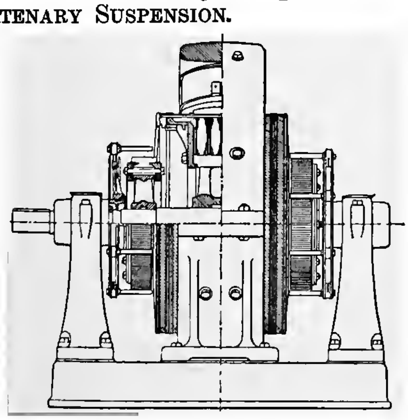
Dolter Surface-contact System. See SURFACE-CONTACT SYSTEM.

Double-boiled Linseed Oil. See LINSEED OIL.

Double-break Switch. See SWITCH, DOUBLE-BREAK; SWITCH TYPES, DESIGNATION OF.

Double-carbon Arc Lamp. See LAMP, ARC.

Double Catenary Suspension. See CATENARY SUSPENSION.


Double-commutator Motor

Double-commutator Motor, a cc electric motor of which the armature is provided with two separate windings and two commutators, one at either end, as shown in the fig. The windings are usually identical in all respects, the object of the system usually being to enable the series-parallel method of control to be used,. without incurring the expense of installing two separate motors. See CONTROL, SERIES-PARALLEL.

Double-current Generator, a cc generator which, in addition to its commutator, is provided with a number of insulated slip rings, connected with appropriate points of the armature winding. By means of brushes applied to the slip rings, ac can be obtained of one, two, or more phases, according to the number and connections of the rings. Both cc and ac can thus be simultaneously generated by the same machine—hence the name.

[In paragraph II of the 1907 Standardisation Rules of the A.I.E.E., a double-current generator is defined as 'a machine for producing both continuous and alternating currents'.]

Double Insulation.—This term is applied to the insulation of *live* parts which are insulated from their supports, which are themselves in turn insulated from ground. Examples of this are to be seen in switchboard instruments, and also in the occasional practice of insulating the frames of electric machines. The insulation of the conductors from the frame or support, is called the *main insulation*, and the insulation of the frame from ground, is called the *secondary insulation*. The use of double insulation is to be avoided, as the attendants are apt to regard the intermediate conductors as being uncharged, whereas they may easily become charged without any warning being given of the fact. The best British practice is distinctly against double insulation, and the frames of all electric machines are usually efficiently *earthed* in this country. [J. S. S. C.]

Double-layer Winding. See WINDING, BARREL.

Double Magnetic Circuit. See MAGNETIC CIRCUIT.

Double-pole (preferable abbreviation *dp*), arranged in relation to two conductors—generally the outgoing and return leads of the same circuit. Thus double-pole switch is frequently written *dp switch*. See SWITCH TYPES, DESIGNATION OF.

Double-pole Cut-out, a circuit breaker or fuse that automatically cuts off current from two leads at once. Such circuit breakers are sometimes operated from one pole only, in which case they are simply single-pole circuit breakers arranged to entirely isolate a circuit instead of opening it at one side alone; in other cases, the breakers have two operating coils, one in each lead, so that the circuit is entirely isolated in the event of an overload in either lead. The expression is also used in connection with fuses, two of which (one in each lead) are often arranged in a common box or casing. A double-pole cut-out is usually referred to as a *dp cut-out.* [F. W.]

Double-pole Switch. See SWITCH, DOUBLE-POLE; SWITCH TYPES, DESIGNATION OF.

Double Pull-off Insulator. See INSULATED HANGER.

Double Spherical Bearing. See 'Self-aligning Bearing' under BEARINGS.

Double-tariff Clock. See SWITCH, TIME.

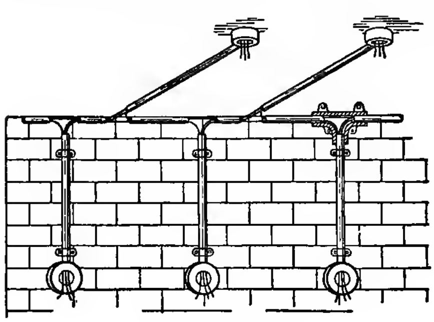
Double-tariff Meter. See METER, TWO-RATE.

Double-tariff System. See TARIFF SYSTEMS.

Double-throw Switch. See SWITCH, DOUBLE-THROW; SWITCH TYPES, DESIGNATION OF.

Doulton Conduit. See CONDUIT, UNDERGROUND.

Down-switch Run, the section of interior conduit tubing running down from



Down-switch Runs

the ceiling to the switches in the wall. In the fig. three *down-switch runs* are shown.

Dp, contraction for *double-pole* (which see).

Drag, Magnetic. See MAGNETIC DRAG.

Draw-bar Pull. See TRACTIVE EFFORT; TRACTION, COEFFICIENT OF.

Draw-in Box.—

['*Draw-in Box,* a box used in connection with a draw-in system of mains. When complete, it contains no links, fuses, or switches, but in some cases it contains permanent joints.'—I.E.C.]

Draw-in Pit. See MANHOLE.

Draw-in System.—

['*Draw-in System,* a system of laying mains in which the cables or wires are drawn into pipes or ducts after the latter have been laid or fixed in position, in such a manner that the cables or wires can be withdrawn at any time without disturbing the pipes or ducts. Draw-in boxes, manholes, or junction boxes are usually provided, through which the cables or wires may be drawn in or withdrawn.'—I.E.C.]

Drawn Filament. See FILAMENT.

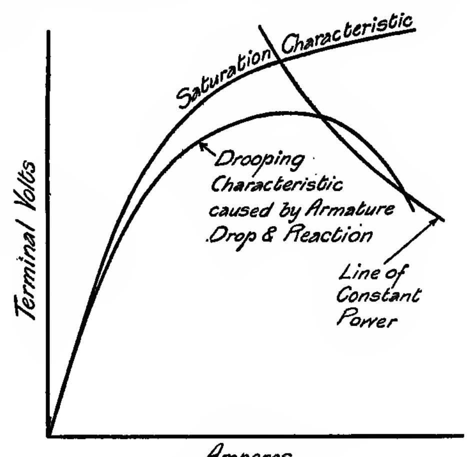
Drifting. See COASTING.

Drill, Electric. See ELECTRIC DRILL.

Driorol, the trade name for a quick air-drying, finishing varnish, for which the manufacturers claim that it will give a good coat on greasy surfaces, and that it is unaffected by lubricating oils. See also FINISHING VARNISHES.

Driving Horn.—In the now obsolete smooth-core armatures some arrangement was necessary to transfer the magnetic pull on the conductors to the body of the armature. For this purpose plates, provided at the face with fork-like projections, were fixed in the core, and the projections took up the tangential thrust from the various conductors. See 'Smooth-core Armature' under ARMATURE.

Drooping Characteristic.—The accompanying fig. shows the curve obtained from



Drooping Characteristic

a series-wound dynamo by plotting the amp load and the terminal volts. After rising in the same manner as the ordinary saturation curve, it becomes flat, and finally bends over, due to the armature reactions and the ohmic drop in the machine. Such a characteristic, known as a *drooping characteristic,* is useful in constant-current and constant-power machines; for if the current in the outside circuit tends, say, to increase, the volts of the machine drop, and so keep the current variations within limits. In the construction of arc-lighting machines, this feature has been adopted to help in steadying the current when different numbers of lamps are switched on. See also CURVE, CHARACTERISTIC.

Drop (in Pressure)—

['*Drop (in Pressure)*, a difference of potential between any two points in a conductor through which a current is flowing, the conductor itself not being the seat of any emf.'—I.E.C.]

Drop, Telephone. See TELEPHONE DROP.

Drop Annunciator. See ANNUNCIATOR.

Drop in Conductor. See FALL OF POTENTIAL.

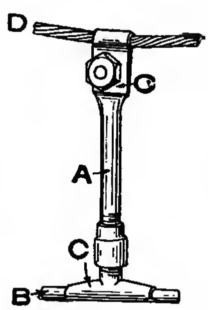
Drop Indicator. See VOLTMETER.

Drop of Voltage. See FALL OF POTENTIAL.

Drop Signal. See ANNUNCIATOR.

Drop Voltmeter. See VOLTMETER.

Dropper, one of the vertical connectors employed in single catenary suspension between the catenary cable proper and the horizontal wire (either trolley or auxiliary wire).



Dropper

A, Dropper. B, Trolley wire. C, C, Clips. D, Catenary cable.

Clips are provided at each end of a dropper. The type shown in the illustration is rigid and more adapted for carrying the auxiliary wire, further flexibility being obtained at the trolley wire by subsidiary droppers interposed between the auxiliary wire and the trolley wire. In the most recent catenary constructions for supporting trolley wires, the tendency has been to depart widely from rigidity, and the droppers are themselves of a light and inexpensive type, and by no means so elaborate as the example shown in the fig. See also CATENARY SUSPENSION.

Drum Armature. See ARMATURE.

Drum Rotor. See ROTOR.

Dry Battery. See BATTERY, PRIMARY.

Dry-core Cable. See CABLE, DRY-CORE.

Drying Off Accumulator. See ACCUMULATOR, DRYING OFF.

Drying Property of Linseed Oil. See LINSEED OIL.

Drysdale Method of Testing Iron and Steel.—In this method, which is particularly applicable to testing iron in bulk, a special form of drill is employed. This drill produces a hole of the form shown in fig. 1, leaving a cylindrical pin standing in

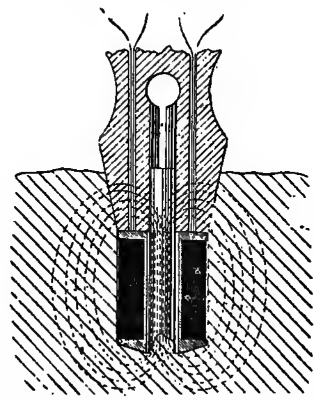


Fig. 1.—Section through Plug and Specimen

its centre. This pin forms the sample of the material to be tested, and the magnetic circuit is completed by means of a soft-iron plug which fits the coned opening of the hole, and simultaneously grips the upper portion of the pin. The plug and drill are made of standard form in such a way that the depth of hole drilled and the length of cone used always leave a definite length of the specimen.

Attached to the lower face of the plug is a small bobbin which exactly fits the parallel portion of the hole. This bobbin carries a search coil and a magnetising coil, the ends of each being brought out of the handle of the plug by flexible cords. These may be connected in the usual way for a ballistic test (see HOPKINSON METHOD OF IRON TESTING; RING METHOD OF MAGNETIC TESTING), or to the special portable testing set devised for the apparatus. This consists of a ballistic galvanometer of the moving-coil type in series with a resistance of such amount that the deflections (read by the aid of a pointer) are, on the scale of the instrument, directly the values of **B**. An ammeter of the moving-coil type is also provided with reversing switch and regulating rheostat, giving definite and convenient values of **H** read directly on the ammeter scale or the ats per in or per cm as desired. The whole apparatus is thus made direct-reading, extremely portable, and compact.

Figs. 2 and 3 show the form of drill and plug, and fig. 4 shows a diagram of the circuit connections. The method of using the instrument may be explained as follows, the letters referring to fig. 4. Adjust the gal-

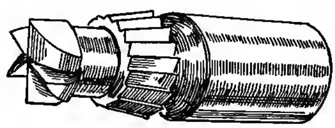


Fig. 2.—Drill employed in Drysdale Method of Testing Iron and Steel

vanometer G to zero. Check the battery current by setting the galvanometer key K and the battery key L to direct position PP, and the switch to battery position B. If the current is not correct, adjust by means of the resistance R. Set the switch back to the permeameter A, and allow the galvanometer G to come to zero. Throw the battery key L from the direct position PP to the reverse

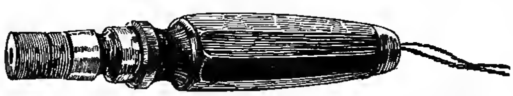


Fig. 3.—Plug employed in Drysdale Method of Testing Iron and Steel

position NN, and read; throw in the galvanometer G. This will give the permeability. Check the result by setting the galvanometer key K to the reverse position NN, allowing the galvanometer G to come to rest. Change the battery key L from the reverse position NN to the direct position PP, and note

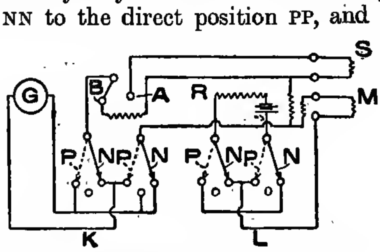
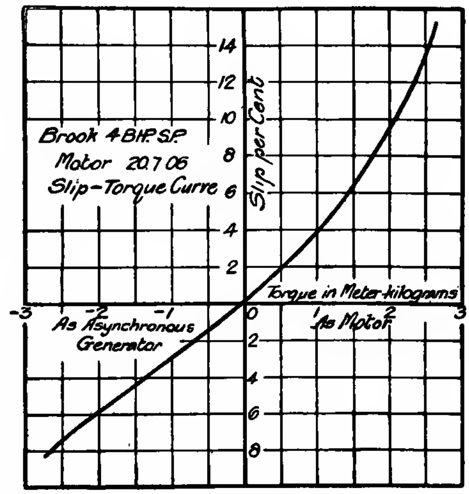


Fig. 4.—Diagram of Connections in Drysdale Method of Testing Iron and Steel.

the throw on G. The complete testing set is illustrated on the accompanying plate. (Ref. Proc.I.E.E., vol. xxxi, p. 283.) See also PERMEAMETER; 'Bridges for Magnetic Measurements' under BRIDGES; IRON AND STEEL TESTING.

Drysdale Stroboscopic Method of Slip Measurement. — In this method a conical roller of boxwood is driven in synchronism with the source of supply by means of a small, synchronous motor. Supported



Slip-torque Curve for Monophase Induction Motors by Stroboscopic Method

on a carriage traversed by a screw in a direction parallel to the axis of rotation of the cone is a delicately pivoted metal disk, which rests on the surface of the cone, and is driven by it. This disk has a number of radial slits, through which a black-and-white sector diagram on the shaft of the motor under test may be viewed, and the disk is traversed until this diagram, seen through the slits, appears stationary. By this means the ratio of the actual speed to the synchronous speed of the machine is directly given on a perfectly evenly divided scale.

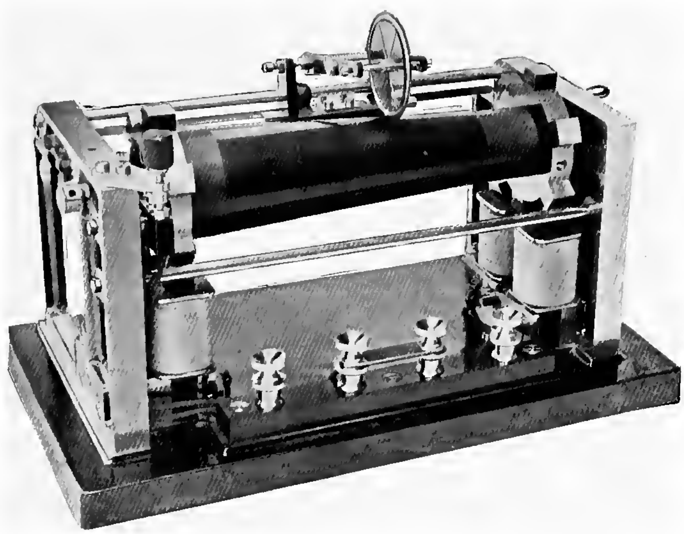
The method is extremely sensitive, and can be made to cover a long range of positive or negative values of the slip.

On the accompanying plate there is an illustration of the roller stroboscope, and the diagram shows a slip-torque curve determined by its aid. (Ref. C. V. Drysdale, Elec., Aug. 25, 1905; Elec. Rev., Sept. 7 and 14, 1906.)

Drysdale Permeameter. See DRYSDALE METHOD OF TESTING IRON AND STEEL; PERMEAMETER; IRON AND STEEL TESTING.

Dt, the preferable abbreviation for *double throw.* See SWITCH TYPES, DESIGNATION OF.

Duct, Ventilating or Air.—In assembling the core of an armature, it is the usual practice to leave open spaces at intervals, through which air may circulate, and so cool the core. The air circulation is pro-

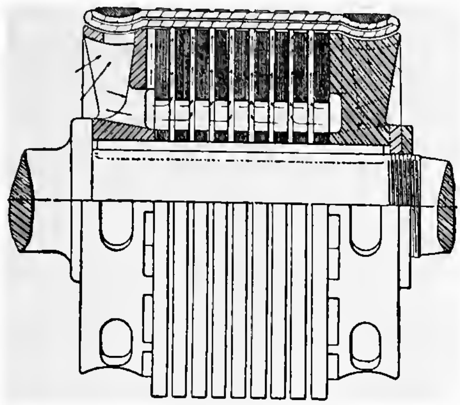


DRYSDALE ROLLER STROBOSCOPIC SLIP MEASURER

DRYSDALE PERMEAMETER TESTING SET

[*To face p.* 174.

vided by the centrifugal action of the moving part. An armature liberally provided with



Ventilating Ducts

ventilating ducts is shown in the illustration. See also DISTANCE PIECE.

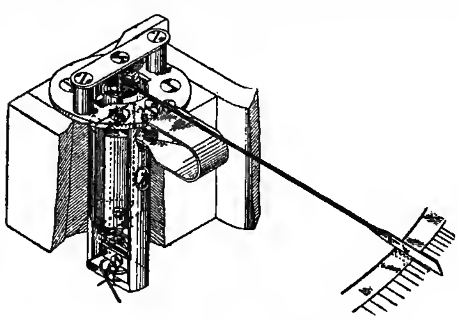
Ducts.—

['*Ducts*, pipes or blocks perforated with holes through which cables are drawn. The holes themselves are sometimes called *ducts*.'—I.E.C.]

See also CONDUIT, UNDERGROUND.

Duddell Oscillograph. See OSCILLOGRAPH.

Duddell Thermo-ammeter, a commercial measuring instrument based on the



Duddell Thermo-ammeter

same principle as the *Duddell thermo-galvanometer*. In the usual pattern the full-scale deflection corresponds to a current of 10 milliamperes. The instrument, which is shown in the figure, is described on p. 94 of the Elec. for May 1, 1908.

Duddell Thermo-galvanometer. See GALVANOMETER.

Dummy Coil. See DEAD COIL.

Duplex Cable. See CABLE, DUPLEX.

Duplex Telegraphy. See 'Multiplex Telegraphy' under TELEGRAPH SYSTEMS.

Duplex Winding. See WINDING, DUPLEX.

Duplex Working. See 'Multiplex Telegraphy' under TELEGRAPH SYSTEMS.

Dust Destructor in Electricity Works. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Dynamic Electricity, electricity in the form of a current as distinguished from static electricity.

Dynamo.—

On p. 1 of vol. i of the 5th ed. (1909) of Hawkins and Wallis's 'The Dynamo', a *dynamo* is defined as 'a machine in which a conductor or system of conductors forming part of an electric circuit is given continuous motion relatively to a magnetic field or fields, and so is caused to traverse or cut the lines of the magnetic flux; an emf is thereby induced in the conductors, so that when the circuit is closed a current flows, and mechanical energy is converted into electrical energy'.

See DYNAMO-ELECTRIC MACHINE.

Dynamo, Alternating-current. See ALTERNATOR; DYNAMO-ELECTRIC MACHINE.

Dynamo, Arc Lighting, a type of dynamo specially designed for supplying constant current to arc lamps in series, often at very h pr, and usually having an armature of the open-coil type; now practically obsolete. See GENERATOR.

Dynamo, Compound-wound. See GENERATOR.

Dynamo, Homopolar. See UNIPOLAR; 'Homopolar Generator' under GENERATOR.

Dynamo, Series-wound. See GENERATOR.

Dynamo, Shunt-wound. See GENERATOR.

Dynamo, Three-wire. See DOBROWOLSKI THREE-WIRE DYNAMO; COMPENSATOR.

Dynamo, Unipolar. See UNIPOLAR; 'Homopolar Generator' under GENERATOR.

Dynamo-electric Machine, a machine for converting work into electricity (or, more precisely, mechanical energy into electrical energy), or vice versa, by means of relative motion between conductors and magnetic fields. When, by this means, a machine converts work into electricity, it is called a *generator* or a *dynamo*. When it converts electricity into work it is called a *motor*. For the first function the term *generator* is preferable to the term *dynamo*; consequently for types of electric generators reference should be made to the definitions in the article GENERATOR. Types of apparatus employed for performing the second function are dealt with in the definitions of the various types of MOTOR.

Generators, as also motors, are for providing either continuous electricity or alternating electricity; but whether for continuous or alternating electricity, there is no alternative to the employment of the term *motor*. But generators for providing continuous electricity are, by many engineers, termed *dynamos*, whereas it is much less usual to apply the term *dynamo* to a generator for providing alternating electricity, such a machine being usually termed an *alternating generator* or *alternator*.

Thus the I.E.C. gives the following definitions:—

I. '*Generator*, any machine capable of transforming mechanical into electrical energy, *e.g.* a dynamo or alternator.'

II. '*Dynamo*, a continuous-current generator.'

This distinction is, however, by no means justified, since the expression *alternating dynamo*, although not so common as *continuous dynamo*, is nevertheless employed. It would be preferable in the future to employ the term *dynamo* for any dynamo-electric machine, whether generator or motor, and to distinguish between *continuous generators* and *alternating generators*, and also between *continuous motors* and *alternating motors*. At present, however, it is often necessary to conform to the customs which have grown up, and which have led to the use in certain cases of the one, and in other cases of the other term. See GENERATOR; ALTERNATOR; DYNAMO; MOTOR; ROTARY CONVERTER; MOTOR GENERATOR; MOTOR CONVERTER; POLYPHASE MOTOR; SINGLE-PHASE MOTOR.

Dynamoes.—In May, 1897, Mordey read a paper before the I.E.E. entitled 'On Dynamoes'. The suggested spelling occasioned considerable discussion, but it was never adopted.

Dynamometer.—

['*Dynamometer*: (*a*) An instrument for measuring forces. (*b*) An apparatus for measuring the torque exerted by a prime mover or motor. (*c*) An instrument for measuring electric currents depending on the measurement of the electromagnetic forces between two or more coils. (Abbreviation for ELECTRO-DYNAMOMETER.)'—I.E.C.]

Dynamometer, Absorption, an instrument for measuring the mechanical-power output of motors, &c., by braking. The power is absorbed either in rubbing friction, wind friction, water friction, or eddy-current losses. The forms most commonly used are as follows:—

1. PRONY OR STRAP BRAKE, in which the torque is produced by the friction between a pulley and a band, and is measured on a beam carried on knife-edges and connected with the band. See PRONY BRAKE FOR TESTING ELECTRIC MOTORS.

2. THE EDDY-CURRENT BRAKE.—The best example of this is Morris and Lister's form, in which two copper disks, mounted on wrought iron, are rotated past the poles of a powerful multipolar electromagnet. The torque is measured by the tendency to rotate the magnet.

3. WALKER'S FAN BRAKE.—Two steel arms carry flat aluminium plates set at right angles to the direction of motion. The power absorbed is measured by the speed, the size of the plates, and their distance from the centre.

See next article and DYNAMOMETER, TRANSMISSION. For 'Soames Absorption Dynamometer' see BAND BRAKE FOR TESTING ELECTRIC MOTORS. [L. M.]

Dynamometer, Air, for Testing Electric Motors.—This piece of apparatus, designed by W. G. Walker, consists of a metal crossarm which is capable of being clamped at right angles to the shaft of the machine to be tested. It is pierced by a number of equidistant holes, which allow of the fixing of flat, aluminium fan blades at various radii, and in this way increasing loads may be put upon the motor. Three sets of blades of progressively larger area are provided, thus giving the apparatus a fairly long range. The power absorbed is calculated by assuming that the power absorbed by the fan is proportional to a constant multiplied by the cube of the speed. A set of constants for every radius and every set of blades accompanies each instrument. See DYNAMOMETER, ABSORPTION. [C.V.D.]

Dynamometer, Siemens, an instrument which measures the power value of a current or the power in a circuit by the product of current and potential. It consists of two coils on a common axis, but set in planes at right angles to each other in such a way that a torque is produced between the two coils and measures the product of their currents.

This torque is balanced by twisting a spiral spring through a measured angle, such that the coils shall resume their original relative positions.

If the instrument is used for measuring

current (see AMMETER), the coils are in series, and the reading is then proportional to the square of the current. If used as a *wattmeter* (which see), one coil carries the main current and the other a small current, which is proportional to the pressure. The reading is then proportional to the power in the circuit. See DYNAMOMETER, WEBER ELECTRO-.

[L. M.]

Dynamometer, Transmission, a piece of apparatus which is placed between the driving machine and the machine being driven, in order to ascertain the power which is being transmitted from one to the other. Transmission dynamometers are of two kinds, viz. belt dynamometers and torque dynamometers.

BELT DYNAMOMETERS.—If the machine is being driven by a belt, then the power it receives from the driver is proportional to the difference of tension between the tight and slack sides of the belt. In the transmission dynamometer designed by Hefner von Alteneck this principle is utilised by making the belt pass between two idle pulleys carried by a movable framework, mounted in such a way that it tends to rise or fall with the change of tension in the sides of the belt, this movement being counteracted by a spring balance or other measuring device. From a knowledge of this force and of other data of the apparatus the difference of tension can be calculated. Great difficulty is encountered in working the apparatus on account of the frequent and violent vibration of the carriage, due to the oscillation of the belt.

TORQUE TRANSMISSION DYNAMOMETERS may be used when the axes of rotation of the driver and of the driven machine are in the same straight line. They are usually in the form of dynamometer-couplings consisting of two parallel disks keyed to each of the shafts and coupled through springs or some elastic material, which gives a torsional displacement proportional to the force applied. The displacement of these disks relatively to one another may be measured by the movements of a system of links and levers, employing the light reflected from a bright bead attached to a definite portion of them to indicate the amount of this motion (Ayrton and Perry), or, better, by the employment of stroboscopic illumination (see DRYSDALE STROBOSCOPIC METHOD OF SLIP MEASUREMENT). The force, which is proportional to the displacement, may be found by calibrating the coupling statically. Considerable trouble is experienced from the effects of centrifugal force on the coupling-springs and other parts of the apparatus, which make the static calibration somewhat doubtful. See also DYNAMOMETER, ABSORPTION.

[C. V. D.]

Dynamometer, Water-brake. See WATER-BRAKE DYNAMOMETER.

Dynamometer, Weber Electro-, an instrument consisting of a fixed coil, with a moving coil hung by a bifilar suspension within it. The coils are concentric, with their axes at right angles. The sine of the deflection is proportional to the square of the current. The readings are the same for cc or ac. See also DYNAMOMETER, SIEMENS; WATTMETER; AMMETER.

Dynamometer, Zero-type. See WATTMETER, DYNAMOMETER ZERO-TYPE; DYNAMOMETER, SIEMENS.

Dynamometer Ammeter. See AMMETER; DYNAMOMETER, SIEMENS.

Dynamometer Wattmeter. See WATTMETER; DYNAMOMETER, SIEMENS.

Dynamotor.—

['*Dynamotor.*—A dynamotor is a transforming device combining both motor and generator action in one magnetic field, with two armatures; or with an armature having two separate windings and independent commutators.'—Paragraph 15 of the 1907 Standardisation Rules of the A.I.E.E.]

Dyne, the force required to impart to a mass of 1 g an acceleration of 1 cm per sec. The dyne is the unit of force in the cgs system, and is equal to the weight of $\frac{1}{981}$ g. See FORCE.

E

Ear.—

['*Ear*, in overhead tramway work, a grooved metal fitting, riveted over, soldered or otherwise attached to, a trolley wire, for the purpose of: (*a*) Supporting the wire. (*b*) Altering the horizontal direction of a trolley wire, termed a *pull off*. (*c*) Anchoring a trolley wire.'—I.E.C.]

Ear, Anchor, an overhead trolley-wire ear arranged with holes to allow of strain

Fig. 1.—Single-ended Anchor Ear

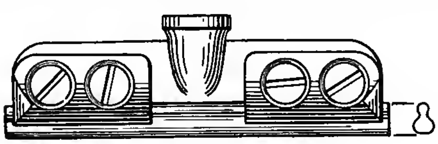
wires being attached to it, and so anchoring it. Forms of anchor ears are shown in figs.

Fig. 2.—Double-ended Anchor Ear

1 and 2. (Ref. 'Electrical Traction', vol. i, p. 125, Wilson and Lydall.)

Ear, Clamping. See Ear, Mechanical.

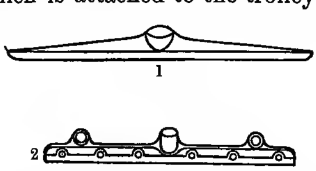
Ear, Mechanical, a supporting ear for overhead trolley wire, so arranged that the



Mechanical Ear

wire is gripped between the two portions of the ear, which are held together by screws, as shown in the fig. Such ears are sometimes called *clamping ears.* (Ref. 'Modern Electric Practice', vol. iv; 'Electrical Traction', vol. i, p. 125, Wilson and Lydall.)

Ear, Trolley, a bronze or gunmetal fitting which is attached to the trolley wire to



Trolley Ears

1, Straight-line ear for round wire. 2, Straight-line anchor ear for grooved wire.

support the latter. The ordinary type of ear is soldered to the wire. There are several kinds of *mechanical ear* which do not require solder, but which can only be attached to figure-8 or grooved wire. Special *anchor*, *splicing*, and *feeder* ears are used instead of *straight-line* ears, for the purposes indicated by their names. See fig.

Earth.—The earth is a conductor of electricity, and in times past this property was utilised to a large extent, especially in telegraph and telephone work. One metallic conductor was used to carry the positive current, and the return current was caused to pass through the earth, connection to the earth being made by large metal plates buried in damp ground. To some extent the system is still in use, but is being gradually abandoned in favour of employing metallic circuits throughout.

Earth connections are, however, largely used for the purpose of ensuring safety from shock. Thus, if any live conductor be efficiently connected to earth, a person touching the conductor cannot receive a shock, since there is no difference of potential between the earth on which he is standing and the conductor which he is touching.

Grounded Terminal.—The terminal of a circuit which is connected to earth is known as a *grounded terminal.*

Bad Earth.—If the connection to earth is inefficiently made, if, for instance, the earth-plate is buried in ground which is dry, the connection is known as a *bad* or *partial* earth.

Intermittent Earth.—It occasionally happens that the ground in which the earth-plate is buried varies in its condition, being sometimes damp and sometimes dry, so that the connection is good at times and at other times bad. Such a connection is known as an *intermittent earth.*

It occasionally happens that, through a fault in insulation, the windings of a machine or the conductors in a circuit become intermittently connected to earth in such a manner as to set up leakage of current.

[c. w. h.]

Creighton (A.I.E.E., vol. xxvi, part ii, p. 1057) gives the following definition for *earths*:—

['*Earths* (connections, resistances, &c.).—The word *earths* is used here specifically to mean the connection between the conductor and the earth in which it is buried. On overhead lines it is usually the only *ground* connection. Length of the earth connection of an arrester is the distance from the arrester to the conducting stratum of the earth. The earth-resistance of a lightning arrester is the ohmic resistance from the arrester to the conducting stratum of earth. Its value may be obtained by measurement between these earthed conductors.']

['*Earth.*—(*a*) An electrical connection with the earth, intentional or unintentional, is called an *earth.* (*b*) (Verb, *to earth.*) To connect any conductor with the general mass of the earth in such a manner as will ensure at all times an immediate and safe discharge of electrical energy. Board of Trade definition of *efficiently connected with earth.* (*c*) *Earth circuit,* a circuit of which the earth forms a part.'—I.E.C.]

See GROUND; EARTH CONNECTION; EARTH-PLATE; CIRCUIT, EARTHED; CONDUCTOR, EARTHED; EARTHED; EARTHING.

Earth Coil. See COIL, EARTH.

Earth Connection.—A conductor making connection to an earth-plate or water-pipe which is at the potential of the earth in the neighbourhood; the expression is sometimes taken to include the earth-plate, pipe, &c., as well as the conductor connected to it.

The Board of Trade Regulations under the Electric Lighting Acts require that the frame of every electric motor supplied from Public Mains under the Acts shall be efficiently connected with earth; that consumers' wires to motors or lamps in series shall, so far as practicable, be enclosed in an earthed metal casing; that all metallic portions of transformers, other than the conductors, shall be earthed; that all metal conduit pipes, &c., containing h pr conductors shall be earthed, and shall be so jointed across street-boxes, &c., as to make good electrical connection throughout their whole length; that covers of street-boxes containing h pr apparatus other than cables shall be connected to strips of metal laid under the street; that all ht apparatus and cables on a consumer's premises shall be completely enclosed in solid walls or in a strong metal casing connected to earth; that where the pressure between adjacent conductors of a three-wire system exceeds 125 volts, the intermediate conductors shall be connected to earth, subject to the concurrence of the Postmaster-General, and in accordance with the following conditions: The connection with earth shall be at one point only on each distinct circuit, namely, at the generating station, substation, or transformer; the current from the intermediate conductor to earth shall be continuously recorded, and if, at any time, it exceed one-thousandth part of the maximum supply current, steps shall be immediately taken to improve the insulation of the system. The maximum penalty is £10 for each default, and £10 daily.

Under the Regulations of the Board of Trade as to electric power on tramways and light railways, it is required that when the return conductor is uninsulated (*e.g.* the rails) it shall be connected to the negative terminal of the generator, which shall also be in connection with two earth plates not less than 20 m apart (see BOARD OF TRADE PANEL), or to a water main of not less than 7·5 cm internal diameter; that where the line or the return is laid in a metal conduit, the lengths of the conduit shall be efficiently jointed so as to be in good electrical connection, and shall be connected to the rails at intervals not exceeding 30 m by copper strips not less than 40 sq mm in area. If the return is wholly insulated, the conduit shall be earthed at the generating station or substation through a high-resistance galvanometer, while the negative conductor shall be connected to earth through a voltmeter.

Under the Board of Trade Regulations concerning guard-wires on electric tramways, it is required that each guard-wire shall be earthed at intervals of not more than five spans, the connection being through the support to the rails by means of a copper bond.

Under the Board of Trade Regulations for railways in metal-lined tunnels it is required that any uninsulated conductor forming part of a return must be connected to the rails at intervals not exceeding 100 ft, by copper strips not less than $\frac{1}{16}$ in in area, or by other means of equal conductivity; that if any part of a return is uninsulated it shall be connected to the negative terminal of the generator, which shall also be connected to the metal lining of the tunnel, unless the lining is otherwise connected to the rails, the connection being in each case made through a suitable current indicator; that if the rails form part of the return they shall be connected at intervals, not exceeding 30 m, to the metal lining of the tunnel by conductors capable of carrying 100 amp without appreciable heating, or they shall not be in any connection with the lining, except at the negative terminal of the generator.

Under the Home Office Special Rules for the installation and use of electricity in mines, it is laid down that all metallic coverings, armouring of cables (other than trailing cables), and the frames and bedplates of generators, transformers, and motors (other than portable motors), shall, so far as practicable, be efficiently earthed when the pressure exceeds the limit of 1 pr; that where a medium-pressure supply is used for power purposes, or for arc lamps in series, or for incandescent lamps in series, the conductors shall, so far as practicable, be completely enclosed in armouring or metal casing connected with earth, or they shall be placed at such a distance apart that danger from fire or shock is reduced to a minimum; this rule does not apply to trailing cables, but does also apply where a higher pressure than medium pressure is used for the supply of motors or transformers.

It is also required that all terminals and live metal on machines over medium pressure above ground, and over 1 pr under ground, shall, when practicable, be protected with insulating covers, or with metal covers connected to earth; that the outer of a concentric cable system may, under certain conditions, be earthed, and that the neutral of a polyphase or three-wire cc system may be earthed at a single point; that when lead-covered cables are used the lead shall be earthed, and shall be electrically continuous throughout. The above-mentioned rules for mines do not apply to telephone, telegraph, and signal wires.

The Regulations issued by the Home Office with regard to the use of electricity in factories and workshops at working pressures between 250 volts and 600 volts specify that all metal holders of incandescent lamps, the frames of all motors, and the metal casing of all wires, switches, fuses, and cut-outs shall be efficiently connected to earth; also, that where the current is derived from a public supply, any metal forming part of the electric circuit shall not be exposed so that it can be touched, unless efficiently connected to earth.

The Wiring Rules of the I.E.E. for pressures not exceeding 250 volts require that if one conductor of a system of supply is earthed no switch or interrupting device must be used on the earthed side unless it is linked with a corresponding device on the non-earthed conductor, so that the two devices shall act simultaneously; that if one conductor is uninsulated at all points—such as the bare return to a concentric system—no switch or fuse may be placed in that conductor, and the said conductor must be efficiently earthed; that where metallic sheathing or tubing is used it must be electrically and mechanically continuous and connected to earth, the earth-wire being of copper not less in area than No. 14 S.W.G. In a dry place, however, isolated single lengths of tubing need not be earthed, if enamelled or otherwise insulated externally. These I.E.E. Wiring Rules further require that gas pipes must never be used as earth connections, and that when mains are earthed at one point, the external conductor of a concentric system must be connected to the earthed main. See also 'Grounded Neutral' under NEUTRAL; EARTH-PLATE; EARTH; CIRCUIT, EARTHED; CONDUCTOR, EARTHED; EARTHED. [F. W.]

Earth Currents. See TERRESTRIAL MAGNETISM.

Earth Detector. See LEAKAGE INDICATOR.

Earth Indicator. See LEAKAGE INDICATOR.

Earth - leakage Cut - out, Wallis - Jones. See WALLIS - JONES AUTOMATIC EARTH-LEAKAGE CUT-OUT.

Earth-plate, a conductor buried in the ground and making good electrical connection with it, to which another conductor or conductors can be attached to bring them to earth potential.

An effective earth-plate can be made of copper sheet No. 16 gauge, some 2 sq m in area, to which the earth-connection of, say, No. 0 gauge is soldered across its whole width, and may also, with advantage, be riveted. The plate should be placed in a hole in the ground with some 60 cm depth of coke or charcoal, crushed to pieces the size of a pea, below it, and with the same amount of coke or charcoal above it. The hole must be of sufficient depth to reach to permanently damp earth, and is filled-in after the plate and coke have been placed in position. If no suitable permanently damp earth can be reached, it may be necessary to run a water pipe to the plate in order to keep the surrounding ground moist.

Earth connections are used, not only to bring some portion of an electrical system to earth, but also to ground the earth side of lightning arresters, and it is most important in all cases that the connection shall be a permanently satisfactory one.

According to the Board of Trade Regulations under the Tramways Act, if the return or any portion of a tramway system is uninsulated, it shall be connected to the negative terminal of the generator, and in such case the negative terminal of the generator shall also be connected to two earth-plates at least 20 m apart, and of such size and so arranged that a pressure not exceeding 4 volts shall produce a current of at least 2 amp from one plate to the other. Under certain conditions connection may be made to a water main instead of to two earth-plates.

A serviceable earth-plate can also be made of a spiral of copper strip, or it may consist of cast iron, preferably with webs or with forked extensions, so as to make as good contact as possible with the coke or charcoal. A brass terminal may be screwed into the cast iron, and the earth wire soldered into this (see GROUND; EARTH CONNECTION; EARTH; CIRCUIT, EARTHED; CONDUCTOR, EARTHED; EARTHED; EARTHING). (Ref. 'Electrical Engineers' Pocket Book', Foster; 'Engineering and Electric Traction Pocket Book', Dawson; also 'Modern Electric Practice', vol. ii, p. 258.) [F. W.]

Earth Rail. See THIRD-RAIL ELECTRIC RAILWAY.

Earth Return.—An electric circuit must form a complete loop, the whole of which is traversed by the current; the loop may consist entirely of metallic wires or other conductors, insulated from the earth wholly or partially, but in some cases it is convenient, in order to complete the loop, to make use of the conductance of the earth, as, for instance, in telegraphy. In this case one pole of the battery or other source of emf is connected to the earth, and the other to the line; at the distant end of the latter, after passing through the receiving instrument, a second connection with the earth is made, and the current flows back to the starting-point by way of the earth, when the circuit is said to have an *earth return.* This course was partly followed also in the early days of electric traction, but is now obsolete for this purpose, though the return conductors are usually uninsulated from the ground, so that a considerable proportion of the current often returns through the earth. An earth return has also been used with advantage in connection with the transmission of power by sp alternating, or by continuous electricity at very h pr.

Earth-wire Ammeter. See LEAKAGE INDICATOR.

Earthed.—

['*Earthed* means connected to the general mass of earth in such manner as will ensure at all times an immediate discharge of electrical energy without danger.'—From definitions accompanying Home Office, 1908, Regulations for Electricity in Factories and Workshops.]

Earthed Circuit.—

['*Earthed Circuit.*—A circuit, one pole of which is earthed at one or more points.'—I.E.C.]

See CIRCUIT, EARTHED.

Earthed Conductor. See CONDUCTOR, EARTHED.

Earthenware Conduit. See CONDUIT; CONDUIT, UNDERGROUND.

Earthing, connecting a point in an electric circuit, or one side of a lightning arrester, or the casing of a transformer, or the frame of a generator or meter, to an earth-plate or to a water main or other conductor which is effectively in contact with earth. See also EARTH-PLATE; EARTH CONNECTION; 'Grounded Neutral' under NEUTRAL; EARTH; CIRCUIT, EARTHED; CONDUCTOR, EARTHED.

Earthing Grips. See GRIPS, EARTHING, FOR WATER MAINS.

Earthing Resistance. See RHEOSTAT.

Earth's Magnetism. See TERRESTRIAL MAGNETISM.

Ebonestos, the trade name of a moulded composition. It is not so hard as many moulded insulators, but is rendered somewhat brittle by heat. It is moistureproof, will take a fairly good polish, and withstands the action of warm mineral oil without disintegration. See 'Moulded Insulators' under INSULATOR.

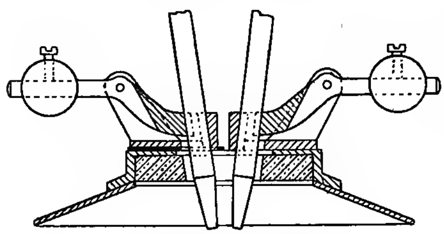
Ebonite, a term applied to hard rubber. See RUBBER.

Eccentric Pole Face.—In order to obtain a sinusoidal distribution of the magnetic flux in the air gap, various devices are used (see POLE SHOE; POLE, COMB). Perhaps the most theoretically correct device is that of the eccentric pole face, in which the pole face, in the case of rotating magnets, is turned to a smaller radius than the bore of the magnet wheel. In this way a gradually increasing gap is obtained, the width at the extreme edge of the pole-tip being generally twice the minimum value. When this is the case, the mean gap-length, for the purpose of saturation-curve calculations, may be taken as $\frac{4}{3}$ the minimum value. [H. W. T.]

Eccentricity of Rotor, the displacement of the rotor of a dynamo-electric machine from its correct position, which is exactly concentric with the bore of the stator. The eccentricity may be defined as the ratio of this displacement to the radial depth of the air gap.

Economical Life of Lamps. See LAMP, INCANDESCENT ELECTRIC.

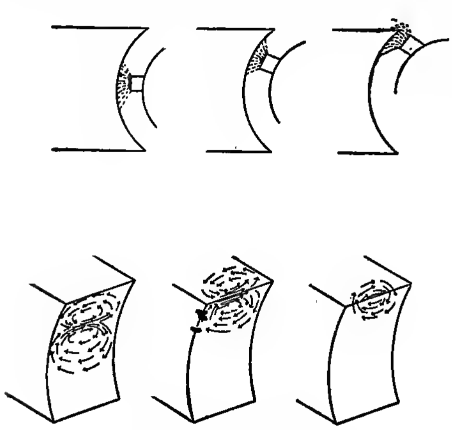
Economiser for Arc Lamp, a shield of refractory material, often of a bowl shape,



Economiser for Arc Lamps

and provided with an aperture or apertures through which protrude the carbons of an arc lamp. The chief object is to reflect downward the light from the arc, and hence the use of an economiser is the more important in arc lamps for alternating circuits. The economiser for a flame arc lamp is illustrated in the fig. See ARC; LAMP, ARC; CARBONS, ARC LAMP.

Eddy Current. — When a conducting body, such as a mass of metal, is swept by



Pole-shoe Eddy Currents

a magnetic field, currents are generated in it, and these are known as *eddy* or *Foucault currents*. The generation of these currents consumes a certain portion of the power of the prime mover, while serving no useful purpose in return, and on this account these currents are sometimes termed *parasitic currents*.

This consumption of power is known as the *eddy-current loss*, and its most important occurrence is in the magnetic circuits of electric machines. These losses are unavoidable in those portions of the machines which are alternately magnetised in opposite directions, but as they are (with constant speed and permeability) proportional to the conductivity of the metal and to the square of its thickness, they may be reduced by choosing a steel having a high ohmic resistance, and using it in laminations as thin as can conveniently be worked. In addition to those eddy losses which are unavoidable, other eddy-current losses may be set up as a result of bad design. Thus, if we use solid pole shoes in combination with an armature having few teeth and wide slots, there will be a tuft (so to speak) of magnetic lines sprouting from each tooth, and as the armature revolves this tuft will sweep past the pole shoe, and will set up eddy currents as illustrated in the fig. The best preventive is to laminate the pole shoes.

EDDY CURRENTS IN YOKES. — In badly designed machines, in which the magnetic flux as a whole fluctuates considerably, eddy currents may even be set up in the yoke, and the losses may even be sufficient to occasion heating at this part. (Ref. Journ. I.E.E., vol. xxxiii, p. 538.)

EDDY CURRENTS IN ARMATURE CONDUCTORS.—Eddy currents also tend to occur in large, solid, slot-wound armature conductors, if the teeth are run at a high density. In such a case the whole of the magnetic lines are not conducted by the teeth, some straying into the slot, and so cutting the conductor. A moderate degree of lamination of the conductor will prevent these losses. See also LOSS, EDDY-CURRENT. (Ref. 'Electric Machine Design', Parshall and Hobart; 'Dynamo-electric Machinery', S. P. Thompson; 'The Dynamo', Hawkins and Wallis.)

[C. W. H.]

Eddy-current Brake. See CRANE, ELECTRIC; DYNAMOMETER, ABSORPTION.

Eddy-current Loss. See EDDY CURRENT; LOSS, EDDY-CURRENT.

Eddy-current Speed Indicator or Tachometer. See SPEED INDICATOR OR TACHOMETER.

Edge-winding for Field Spools.—This form of winding is used for field spools wound with conductors of large sectional area. A flat-strip conductor is used, and this is wound on edge instead of on the flat. By this means the heat generated in the interior of the spool is conducted directly to the outer surface, instead of being confined by successive layers of insulation, as would be the case if the conductor were wound on the flat. A field spool wound in this manner may be given a fine appearance by polishing the edges. Such a spool generally has a high *space factor* (which see).

Edgewise Instrument. See INSTRUMENT, SWITCHBOARD MEASURING.

Edison-Brown Plastic Bond. See BOND.

Edison-Hopkinson Dynamo. See GENERATOR.

Edison-Lalande Battery. See BATTERY, PRIMARY.

Edison Screw Cap. See CAP OF INCANDESCENT LAMP.

Edison Screw Holder. See LAMP HOLDER.

Edison's Nickel-steel Accumulator. See ACCUMULATOR.

Too late for insertion under ACCUMULATOR, there have come to hand the particulars of an important modified type of *Edison's nickel-steel accumulator.* Owing to the important claims made for this accumulator, as, for instance, that for a given weight it has twice the capacity of other accumulators, the following description is inserted at this point, and it will be found that the accumulator differs materially from the earlier type described in the article on ACCUMULATOR.

The accumulator is built with especial reference to use on automobiles. It is very light, and it is claimed to be exceedingly durable. It is made in two sizes, one with four positive and five negative plates, and one with six positive and seven negative plates. The average discharge-pressure per cell is 1·2 volt. The rated capacity of the small-sized cell is 150 amp hr, and that of the large size is 225 amp hr. The normal rates of charge and discharge are 30 amp in the first case, and 45 in the second. The weight of the small cell is 6·2 kg, and its dimensions are approximately 38 cm × 13 cm × 6·5 cm. The large-sized cell weighs 8·8 kg, and measures approximately 38 cm × 13 cm × 9·5 cm. The cells may be charged at twice the normal rates, *i.e.* they may be charged at 60 and 90 amp if the temperature is kept below 55° C. But the rate of discharge (if maintained for long periods) should preferably not exceed the normal figure, although for *very short periods* discharge rates up to three times the normal figure are permissible. It is stated that *overcharging* is not harmful to the accumulator, and that the accumulator does not deteriorate if left discharged for long periods.

The active materials consist of nickel oxide in the positive plate, and iron oxide in the negative plate. The electrolyte consists of a 21-per-cent solution of potassium hydrate, to which is added a small amount of lithium hydrate. The function of the lithium hydrate is stated to be not clearly understood, but its presence has been found to improve the working of the positive electrode. The density of the electrolyte does not vary with the charge and discharge. It should be about 1·21 throughout the cycle, but it is stated that the efficiency and capacity of the accumulator are hardly affected if, in replenishing the cell, there should be a lowering of the density of the electrolyte to 1·16; but this should be regarded as the lowest suitable limit. The active parts are enclosed in corrugated and electroplated steel cans.

The negative plate is made up of flat rectangular pockets, composed of thin nickel-plated steel, perforated with fine holes, and filled with oxide of iron The positive plate, unlike the earlier types, consists of thin perforated steel tubes, and an enclosing nickel-plated steel grid. In place of the graphite employed in the positives of the earlier types, these steel tubes contain nickel oxide and flakes of pure nickel.

Effective Current. See ROOT MEAN SQUARE.

Effective emf. See ROOT MEAN SQUARE.

Effective Voltage. See ROOT MEAN SQUARE.

['*Effective volts,* a term not to be recommended. See VIRTUAL VOLTS.'—I.E.C.]

Efficiency.—Efficiency is the relation of the energy given out by a machine to the energy supplied to it, and is generally expressed as a percentage. The difference between the input and the output constitutes the loss in conversion.

The OVERALL or COMMERCIAL EFFICIENCY

of a dynamo is the relation of the electrical energy given out from its terminals to the mechanical energy supplied to its pulley, in the case of belt-driven machines, or to its shaft, in the case of direct-coupled ones.

Electrical Efficiency.—In comparing the performances of dynamos another figure formerly often, but now rarely, employed is the *electrical efficiency.* A portion of the electricity generated in a dynamo is used in the machine itself for overcoming the resistance of the windings and supplying current to the shunt coils. The electrical efficiency is the ratio which the electricity given out at the terminals bears to the total electricity generated in the machine, the iron losses and the friction thus being neglected. Some of the losses in the machine vary with the load, while others are independent of it. Hence the efficiency is not constant for all loads. Generally the full-load efficient is highest, the efficiency decreasing as the load becomes less or greater than full-load. Better practice, however, is to design the machine to give its highest efficiency at its *average* load. In specifications of dynamos it is customary to stipulate the full, three-quarters, and half-load efficiencies, so as to give some guide as to the efficiency of the machine at different loads.

Combined Efficiency.—In the case of a dynamo coupled direct to a steam or gas engine, the combined efficiency is the relation of the electrical energy at the terminals of the dynamo to the ihp in the cylinder of the engine.

Apparent Efficiency.—In the case of alternating motors this term is sometimes employed, since in alternating motors the product of the pressure in volts and the current in amp will usually be greater than the w. In other words, the *apparent* input is greater than the *true* input, and the apparent efficiency, which is the ratio of the output to the apparent input, is lower than the true efficiency.

The efficiency of a complete plant is the relation of the energy-output of the plant to the energy contained in the fuel consumed, in the case of steam or gas plants, or the energy contained in the water passing through the turbines, in the case of a hydro-electric plant. See Central Station for the Generation of Electricity; Mining Equipment, Electrical.

All-day Efficiency.—As the load on a plant varies throughout the day, the all-day efficiency is the relation of the average output throughout the day to the average energy put into the machinery in the same time. See 'All-day Efficiency of Transformer', defined below.

Torque Efficiency, in the case of motors, is the relation of the torque exerted at the driving shaft to the torque developed at the armature conductors, the difference being accounted for by the iron losses and the friction of the bearings.

Thermal and Thermodynamic Efficiency.—The terms *thermal* and *thermodynamic*, as applied to efficiency, have been used somewhat indiscriminately by different writers. The most correct use of these terms is as follows. The thermal efficiency of a steam-driven electric generating set is the ratio of the energy delivered from the electric generator in the form of electricity to the energy in the steam in the form in which it is admitted to the steam engine. The thermodynamic efficiency of such a set is the ratio of the energy delivered from the electric generator in the form of electricity to that portion of the energy in the steam at admission, which could, in a steam engine of 100-per-cent efficiency, be delivered from its shaft as work, under the accompanying conditions as regards admission temperature and pressure and exhaust pressure. Since the *convertible* portion of the energy in the steam is, with commercially attainable exhaust pressures, but a comparatively small proportion of the total energy in the steam at admission, the thermodynamic efficiency is always far higher than the thermal efficiency. (Ref. 'Heavy Electrical Engineering', pp. 13 to 17, Hobart.)

Transformer Efficiency, the ratio (usually expressed as a percentage) between the output from, and the input to, a transformer. The loss in a transformer may be divided into two parts, viz. (1) that in the iron core, due to hysteresis and eddy currents, and (2) that in the copper windings, due to resistance. There is also a further loss in the copper, particularly when heavy conductors are used, due to eddy currents induced by the leakage flux. This last loss is sometimes known as *load loss.* The efficiency of transformers is, in general, higher than that of other electrical machines; even in quite small sizes it reaches over 90 per cent, and in the largest is frequently as high as 98·5 per cent.

To measure the efficiency of a transformer directly, by measuring input and output, does not constitute a satisfactory method when the efficiency is so high. A very accurate result can be obtained, however, by measuring separately, by wattmeter, the core and copper losses. The core loss is measured by placing a wattmeter in circuit when the transformer is on circuit at no-load and normal frequency. The copper loss is measured by placing a wattmeter in circuit with the primary when the secondary is short-circuited, and when enough pressure is applied to cause full-load current to flow. If it is desired to separate the load losses from the true I^2R loss, the resistances can be measured, and the I^2R loss calculated and subtracted from the wattmeter reading. The losses being known, the efficiency at any load is readily found by taking the core loss as constant and the copper loss as varying proportionally to the square of the load. Thus, efficiency

$$= \frac{\text{output}}{\text{output} + \text{losses}} \times 100.$$

ALL-DAY EFFICIENCY OF TRANSFORMER denotes the ratio of the total w hr output of a transformer to the total w hr input, taken over a working day. To compute this efficiency it is necessary to know the load curve of the tranformer over a day. Suppose that this is equivalent to 5 hr at full-load, and 19 hr at no-load. Then, if W_1 be the w core loss, W_2 the copper loss at rated load, and W the rated output, we have:

$$\text{Output} = 5 \times W \text{ w hr},$$
$$\text{Losses} = 5(W_1 + W_2) + 19\,W_1,$$
$$\text{Input} = 5(W + W_1 + W_2) + 19\,W_1,$$

and the all-day efficiency is equal to

$$\frac{5\,W \times 100}{5(W + W_1 + W_2) + 19\,W_1} \text{ per cent.}$$

A transformer designed for a high all-day efficiency should have a low core loss as compared with its copper loss.

[The following definition constitutes §§ 87–88 of the 1907 Standardisation Rules of the A.I.E.E.:—

'The *efficiency* of an apparatus is the ratio of its net power output to its gross power input.

'*Note.*—An exception should be noted in the case of storage batteries or apparatus for storing energy, in which the efficiency, unless otherwise qualified, should be understood as the ratio of the energy output to the energy intake in a normal cycle. An exception should also be noted in the case of luminous sources.

'*Apparent Efficiency.*—In apparatus in which a phase displacement is inherent to their operation, apparent efficiency should be understood as the ratio of the net power output to the volt-amp input.

'*Note.*—(*a*) Such apparatus comprises induction motors, reactive synchronous converters, synchronous converters controlling the pressure of an alternating system, self-exciting synchronous motors, potential regulators, and open magnetic circuit transformers, &c.

'*Note.*—(*b*) Since the apparent efficiency of apparatus delivering electric power depends upon the pf of the load, the apparent efficiency, unless otherwise specified, should be referred to a load pf of unity.']

See ENERGY LOSSES; ACCUMULATOR, EFFICIENCIES OF; LAMPS, EFFICIENCY OF. For Efficiency of Gearing, see GEARING FOR ELECTRIC MOTORS.

Efficiency, Copper.—In electric machines the copper efficiency may be stated as the output in w per kg of copper used in the construction of the machine; the comparison being made between machines of equal temperature-rise, speed, &c. In well-designed, well-ventilated machines the output in w per kg of copper will be much higher than in machines in which the ventilation is bad, or in which the magnetic flux is not carried up to its most economical value.

Efficiency, Overall, of an Electric Generating Station. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Efficiency, Radiant.—The radiant efficiency of a source has been defined as the percentage of the total radiation of every description of the source which is available in a visible form, *i.e.* between the approximate limits of 0·4 μ and 0·8 μ.

The value of the radiant efficiency depends upon the range of the spectrum which is regarded as visible. In a recent determination Dr. Drysdale assumes this to be 0·39 μ to 0·76 μ. ('Proc.Roy.Soc.', vol. 80, 1907.)

As usually determined, this quantity does not include convection and conduction losses, and merely refers to the energy actually radiated in any direction. The term *luminous efficiency* or *total efficiency* has been used to define the percentage of energy available in a luminous form, including also these losses.

Efficiency, True. See TRUE EFFICIENCY; EFFICIENCY.

Efficiency of Spur Gear. See GEARING FOR ELECTRIC MOTORS.

Effort, Turning. See TURNING EFFORT.

Ehp, the preferable abbreviation for *extra high pressure.* See PRESSURE.

Ehp, an abbreviation for *electrical horse power* (see HORSE POWER). It is time that engineers should relegate to oblivion the terms hp and especially ehp, and employ more modern units of power, such as the *kg m ph* and the *kw.*

Eht, the preferable abbreviation for *extra high tension,* which is synonymous with *extra high pressure.* See PRESSURE.

Eickemeyer Bridge. See BRIDGES.

Eickemeyer Coil. See COIL, FORM-WOUND.

Einthoven Galvanometer. See GALVANOMETER.

Ejector Condenser. See CONDENSER, STEAM.

Elastic Insulating Varnishes, sometimes called *plastic insulating varnishes.* These are baking varnishes which, it is claimed, remain permanently plastic, by suspending oxidation, after the varnish has become thoroughly dry. Such varnishes are usually black, and take longer to dry than the ordinary insulating baking varnishes. There is, however, no known means of preventing the absorption of oxygen by a drying oil, so that they only remain more pliable for the earlier part of their life. Nearly all the manufacturers of insulating varnishes now supply an insulating varnish for which they claim permanent plasticity. (Ref. 'The Insulation of Electric Machines', chap. viii, Turner and Hobart.) See also INSULATING VARNISHES. [H. D. S.]

Elastic Limit. See MODULUS OF ELASTICITY.

Electric (and Electrical), pertaining to electricity.

Electric Accelerometer. See ACCELEROMETER.

Electric Baking Oven, a baking oven for coils and insulating materials, which is electrically heated. The advantages of this method are the absolute dryness of the heat, and the ease of control. But except where electricity is available at a low price, electricity is a rather expensive means for heating an oven. See OVEN, BAKING.

Electric Brake. See BRAKES.

Electric Breaking Strength, the power of an insulating body or material to resist breakdown by dielectric strain. It is usually measured by the disruptive voltage of the body in question.

BAUR'S LAW FOR ELECTRIC BREAKING STRENGTH.—This law was formulated by Baur in the following form: 'Every dielectric, whatever its thickness, requires a certain voltage to break it down, and this is proportional to the two-thirds power of its thickness'. Thus, if V be the breakdown voltage of a sample, of thickness *d*, $V = cd^2$, where *c* is a constant for the material, and is called by Baur the *electric breaking strength.* This law cannot be regarded as representative of all good results of tests on voltages of breakdown. Dr. Walter's formula, $V = a + bd$ (where *a* and *b* are constants for a given material) is equally near the truth. (Ref. 'Insulation of Electric Machines', p. 49, Turner and Hobart; Baur, Elec., 1901, p. 759; E.T.Z., 1904, p. 7; Walter E.T.Z., 1904, p. 874.) See DISRUPTIVE VOLTAGE; DIELECTRIC STRENGTH.

Electric Cab. See CAB, ELECTRIC.

Electric Canal Traction. See CANAL TRACTION, ELECTRIC.

Electric Car. See CAR, ELECTRIC.

Electric Circuit. See CIRCUIT, ELECTRIC.

Electric Clock, a clock either driven and controlled electrically, or merely controlled by intermittent currents. The controlling or master clock must be an accurate timekeeper, and must control the electric currents which are distributed to the other clocks. Installations of electric clocks controlled from the local astronomical observatory are now common in most cities. Many technical colleges and other large institutions have private installations consisting of a master clock, which controls clocks placed in each classroom, by current impulses delivered every min or half-min. The control may also be wireless.

Electric Coal-cutter, a machine used for holing the coal in a coal seam, and driven by an electric motor.

Broadly classed, there are two methods of mining coal: (*a*) the pillar-and-stall method, (*b*) the long-wall system. In the United States, India, Japan, and other countries where the seams are relatively thick, the former method, in plan like a chessboard (alternate squares being worked as stalls at one time), is usually employed. A coal-cutting machine specially suited to this work has been designed in the United States. It may be described as a *coal-heading machine,* since it works by driving a comparatively narrow *heading* into the coal face. It consists of a frame about 5 ft 6 in wide, round which runs a chain driven by an electric motor; the frame is advanced into the face, undercutting it to the width of the frame, and to a depth of about 6 ft. It is then withdrawn and moved laterally into position for the next cut.

In Britain the coal is generally mined on the long-wall system, and this method is favourable to the best results from machine working.

Comparatively long coal faces are prepared for *long-wall* working, and the machine, instead of cutting a *heading* into the face, is put under the coal to the maximum depth of which it is capable, this depth varying from 3 ft to 4 ft, according to the size of the machine, and is then pulled along the face, undercutting it as it goes. The length of the face depends on the thickness of the coal, the soundness of the roof, and on other local conditions. In seams under 3 ft thick, a face about 100 yd long can be undercut in one night-shift, and the coal cleared during the day, so that the face is ready for the machine again at night. In thicker seams the quantity of coal cut in one night is too great to be cleared in one day, and it is then usual to have much longer faces, up to 1000 or 1200 yd in length, and to have several machines following each other at considerable intervals along the face.

There are three types of long-wall coal-cutters. The first of these is the *disk coal-cutter*, in which the motor drives, through

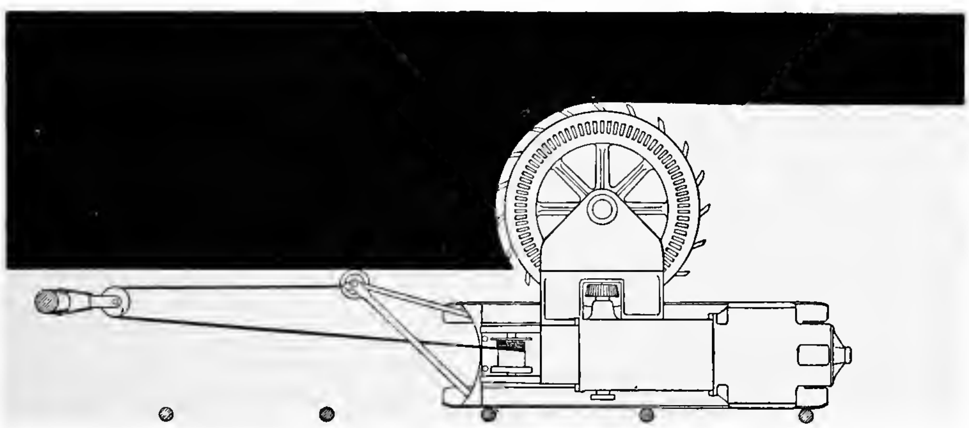


Fig. 1.—Disk Electric Coal-cutter

gearing, a horizontal disk, to the periphery of which the cutting tools are attached. The second is the *bar coal-cutter*, consisting of a bar carrying the cutting tools on its periphery. The bar is driven by an electric motor, through gearing adapted not only to rotate the bar, but also to give it a reciprocating motion, and is so arranged as to allow the bar to be swung round in a horizontal plane. The bar is set rotating when lying parallel to the coal face, and is gradually swung round, cutting its way into the coal until it is at right angles to the face.

The third type is the *chain coal-cutter*, in which the cutting tools are carried by a chain which works round pulleys on a frame, which is worked in under the coal seam.

In all three types of machine, after the cutting tools have been worked into the coal to the maximum depth of which the machine is capable, the whole machine is moved along the face by means of a haulage rope, worked by the electric motor, undercutting as it goes along.

The *disk* machine was the first in the field, and the *chain* machine was introduced from America, but has not met with much success in Britain. The *bar* machine, which was introduced some seven or eight years ago, has grown rapidly in popularity, and is now extensively used in all the coalfields. Several special advantages are claimed for it: (*a*) freedom from likelihood of jamming by falling coal; (*b*) ability to cut its own way into the coal at the beginning of the face, instead of requiring a hole to be cut by hand for it to start work in; (*c*) small width, so that the timber props may be close to the coal face.

Under a good roof, and with strong coal, there is probably little to choose between the *bar* and the *disk* type, but with a bad roof or tender coal, the *bar* machine appears to have points in its favour, especially in its comparative freedom from jamming.

As may be said of all portable tools, the work done by an electric coal-cutter depends largely on the personal element in its management. It has been shown, however, that an output of 20,000 tons per annum is not unusual from a long-wall machine in a seam about 2 ft 6 in thick.

Any of the machines described may be driven either by continuous motors or by polyphase induction motors. The supply is brought to suitable distributing boxes at the gate ends, and from the nearest of these a flexible cable is brought to the machine and is carried along the face with it.

Fig. 1 represents an electric coal-cutter of the *disk type*, and fig. 2 represents a machine of the *bar type*. The latter is built under the trade name of the *pickquick coal-cutter*.

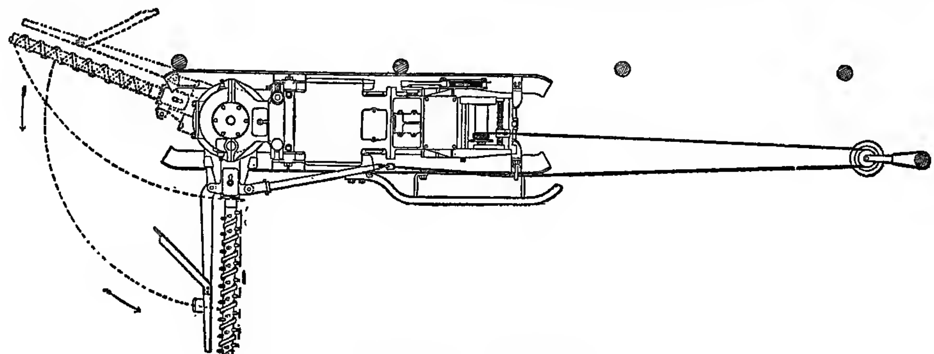


Fig. 2.—Bar Electric Coal-cutter (Pickquick)

(Ref. Sam. Mavor, 'Practical Problems of Machine Mining', Trans. Inst. Mining Engineers, June 14, 1906; W. E. Garforth, 'Applications of Coal-cutting Machines to Deep Mining', Trans. Inst. Mining Engineers, 1902, vol. xxiii, p. 312; 'Electricity in Mining', Hutchinson and Ihlring; 'Electricity applied to Mining', Lupton, Parr, and Perkin.) [W. B. H.]

Electric Control of Pneumatic Apparatus. See CONTROL, ELECTRIC, OF PNEUMATIC APPARATUS.

Electric Current. See CURRENT, ELECTRIC.

Electric Discharge. See DISCHARGE, ELECTRIC.

Electric Drill, a rotating boring tool driven by electric power, used for drilling rivet holes in shipbuilding, and for many similar purposes, also in dentistry. Rowan's electric drill holds itself against the plate to be drilled by the pull of a powerful electromagnet contained in the frame of the drill.

Electric Energy. See ENERGY.

Electric Field, a region in which there is electric force, whether steady or varying. The term *electric field* is also used in a quantitative sense, meaning the amount or intensity of the force. See LINE OF INDUCTION; MAXWELL.

Electric Force, the mechanical force on a unit particle of electricity in an electric field; in general, the force caused by the interaction of electric fields. See also FORCE.

Electric Furnace. See FURNACE, ELECTRIC.

Electric Intensity. See FORCE.

Electric Launch, a boat propelled by electricity. The electric motor is coupled directly to the propeller shaft, and is supplied with power from a battery of accumulators, which are charged, when necessary, at fixed charging stations.

Electric Lighting Acts.—The expression, as employed in the 1909 Electric Lighting Act, means: (*a*) As respects England and Ireland, the Electric Lighting Acts, 1882 and 1888; and (*b*) as respects Scotland, the Electric Lighting Acts, 1882 and 1888, the Electric Lighting (Scotland) Act, 1902 (Electric Lighting Act, 1909, Clause 25).

Electric-light Station. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Electric Locomotive, a vehicle equipped with electric motors and controlling apparatus, for the purpose of hauling trains of cars or wagons on a railway.

Electric Meter. See METER, ELECTRIC.

Electric Oscillation, a state characterised by a quantity of energy being alternately stored in a potential and in a kinetic form, accompanied by an ac. Thus, if a charged condenser, or Leyden jar, be allowed to discharge through a circuit having self-induction and a sufficiently small resistance, the discharge current will be oscillatory. As the condenser discharges there will be a rush of current throughout the circuit, and, owing to the electromagnetic inertia, or self-induction of the circuit, this current will continue to flow after the charge of the condenser has reached zero value. The condenser will thus become charged in the opposite sense, the current falling to zero value as the energy reabsorbed reaches the original value, less any loss which may be due to ohmic resistance, radiation, &c. The condenser, now charged in the opposite sense, will again discharge, and the process will be repeated until the original store of energy is frittered away and dissipated in heat, radiation, or otherwise. The energy is alternately stored in the potential state, *i.e.* electrostatically, in the condenser, and in the kinetic state, *i.e.* electromagnetically, in other words, in the magnetic field which is interlinked with the circuit when the current in the circuit is the maximum and the charge in the condenser is zero. See OSCILLATION; DISCHARGE, OSCILLATORY. [M. B. F.]

Electric Potential. See POTENTIAL, ELECTRIC.

Electric Power-rooms.—These are defined by the V.D.E. (which see) as 'rooms in which electrical machinery or apparatus is installed, and into which only authorised persons are admitted'.

CLOSED ELECTRIC POWER-ROOMS are such as are only occasionally entered by authorised persons, but which are usually under lock and key, and can only be opened by such persons as are duly authorised to enter. (Ref. Journ.I.E.E., vol. 41, p. 167.)

Electric Propulsion, the employment of electric power for propelling or driving vehicles and boats by means of apparatus carried thereon.

Electric Radiation. See RADIATION.

Electric Stress. See STRESS, ELECTRIC.

Electric Subway. See SUBWAY.

Electric Telegraph, a means for the transmission of intelligence by electric currents, which are reversed, interrupted, or otherwise varied from time to time by the sender to form signals which are interpretable on a prearranged code (see MORSE ALPHABET). The apparatus consists of a transmitter, controlled directly or indirectly by an operator, which produces the current and varies it as desired; a line wire, which conducts the current to the receiver; and a receiver, which makes apparent the variations of current, and so gives readable signals. A return wire or earth connections are necessary if the current is unidirectional or of lf. A simple form consists of a battery and key as transmitter, with a galvanometer or a sounder as receiver.

Electric Thermometer. See PYROMETER, ELECTRIC.

Electric Traction. See TRACTION, ELECTRIC.

Electric Train, a number of railway vehicles coupled together, and propelled by electric motors, or hauled by an electric locomotive.

Electric Transmission of Energy. See ENERGY, ELECTRIC TRANSMISSION OF.

Electric Tube. See TUBE, ELECTRIC.

Electric Valve, Nodon. See RECTIFIER.

Electric Wave Telegraphy. See WIRELESS TELEGRAPHY.

Electrical, synonymous with *electric.* Custom alone affords guidance as to which of these two words to use in any case.

Electrical Absorption. See ABSORPTION, ELECTRICAL.

Electrical Conductivity. See CONDUCTIVITY.

Electrical Efficiency. See EFFICIENCY.

Electrical Energy, System of Charging for. See TARIFF SYSTEMS.

Electrical Engineering. See ENGINEERING, ELECTRICAL.

Electrical Measuring Instruments. See AMMETER; METER; VOLTMETER; WATTMETER; INDICATOR, PHASE OR POWER FACTOR; INSTRUMENT, RECORDING; INSTRUMENT, SWITCHBOARD MEASURING.

Electrical Power Storage Accumulator. See ACCUMULATOR.

Electrically-welded Rail Joint. See WELDED RAIL JOINT.

Electricity, a definite and measurable physical entity, which is the essence of certain manifestations of natural activity. The nature of electricity is conjectural; we have not yet succeeded in forming an adequate conception of it in terms of our familiar conceptions. The name is derived from a Greek word meaning *amber,* in which substance certain electrical phenomena were originally studied.

Electricity may exist in the form of a charge on matter. In this form, two kinds are to be observed, known respectively as *positive* or *vitreous* electricity, and *negative* or *resinous* electricity. Charges repel like, and attract opposite charges according to the law of inverse squares (see LAW, COULOMB'S). Electricity in this form is known as *static electricity* (which see), and its study as *electrostatics* (which see).

Charges of electricity on conductors are quite mobile, and distribute themselves on the surfaces of the conductors, so that the potential energy of the system may be a minimum, according to the universal law for systems in equilibrium. This is when each conductor is at one potential throughout (see POTENTIAL, ELECTRIC). Any change in the position or magnitude of any of the charges of electricity will, in general, cause a redistribution of the other charges, in order to again attain the condition of minimum potential energy. During the time that such a redistribution is taking place, the electricity exists in the form of a so-called *electric current.* Electricity in the form of a current is known as *voltaic* or *dynamic* electricity, and its study as *electro-kinematics.*

According to modern views, electricity in the form of a charge on a conductor is really the manifestation of a state of polarisation in the dielectric surrounding the conductor. This is expressed by saying that a displacement of electricity takes place in the dielectric, from the conductor to surrounding bodies, if it is positively charged, and from surrounding bodies to the conductor if it is negatively charged. The total amount of the electric displacement is equal to the charge on the conductor. The electricity, therefore, which enters the body as a *conduction current,* leaves it at the same time as a *displacement current.* Whatever may be the nature of electricity, it cannot be generated, destroyed, or accumulated, it can only be displaced or circulated. This is implied in the statement that the motions of electricity are like those of an incompressible fluid, or that electricity always flows in closed circuits. See CURRENT, ELECTRIC.

We may therefore conceive of electricity as something which is displaced by a definite amount when an emf is applied to a dielectric, which remains displaced as long as the emf is continued, but is restored on its removal, in virtue of the electric elasticity of the medium. It is also displaced in a conductor, which, however, yields to the stress, having no elastic force to restore the electricity on the removal of the emf. The electricity accordingly continues to flow in the form of a current as long as the emf remains, and the displacement in this case is permanent.

The practical unit used in the measurement of quantities of electricity is the *coulomb* (which see). [F. W. C.]

Electricity.—The preceding definition is based on the *physical* conception of electricity. Commercially, and also as usually employed by engineers, the term electricity is applied to electrical *energy,* which may thus be called electricity. In this sense, the unit of electricity is the kelvin, which is the amount of energy corresponding to one kilowatt maintained for one hour, *i.e.* to one kilowatt-hour (1 kw hr). This quantity of energy has also been widely designated—in the past—as *one Board of Trade unit.* Exception may be taken to defining electricity as energy, as this conflicts with the physicists' conceptions. Since, however, on 99 per cent of the occasions when the word *electricity* is uttered, it is, whether consciously or unconsciously, electrical energy which is meant, it would appear undesirable to endeavour to stem this practice and relegate the use of the word to the physicists' purposes.

As a typical instance of the meaning attached to the word electricity by the average man, the following quotation from Shaw's 'Man and Superman' may be given:—

> 'If you study the electric light with which I supply you, you will find that your house contains a great quantity of highly susceptible copper wire which gorges itself with electricity and gives you no light whatever. But here and there occurs a scrap of intensely insusceptible, intensely resistant material; and that stubborn scrap grapples with the current and will not let it through until it has made itself useful to you as light and heat.'

Electricity, Alternating, electricity in the form in which the current component alternates in direction many times per sec; often called *alternating-current electricity,* but this is an undesirably cumbersome expression.

Electricity, Atmospheric. See ATMOSPHERIC ELECTRICITY.

Electricity, Continuous, electricity in the form in which the current component is continuously in one direction; often called *continuous-current electricity,* but this is an undesirably cumbersome expression for so useful a term.

Electricity, Frictional. See FRICTIONAL ELECTRICITY.

Electricity, Storage of. See STORAGE OF ELECTRICITY.

Electricity Supply Meter. See METER, HOUSE SERVICE (and other definitions relating to types of meter).

Electricity Supply Station, a station containing prime movers driving electric generators from which electricity is collected so as to be delivered from the station to a conducting system to which the consumers' circuits are connected. Synonymous with *generating station* (which see). See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Electricity Works. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Electrification by Cleavage. See CLEAVAGE, ELECTRIFICATION BY.

Electrification of Railways, the conversion of existing railways to electrical operation. The electrification of urban, suburban, and interurban railways has been attended with great success, but no considerable progress has yet been made with the electrification of main-line railways. All railway electrification projects involve heavy initial expenditures, which are usually chiefly justified by the increased traffic rendered practicable by electric as compared with steam working. Where, as on most *main-line* railways, any increase in traffic which can be anticipated can be efficiently met by steam haulage, the justification for employing electrical methods is less apparent. The advantages of substituting electric methods are greater the greater the annual ton-mileage to be handled per annum per mile of track, and the more limited the terminal accommodations. Railways with a considerable mileage of tunnels can be operated electrically much more satisfactorily than with steam, owing to the absence of smoke. The economic advantages of electrifying railways are greater the lower the cost of producing electricity. In England, the North-Eastern Railway, the Midland Railway, the Lancashire and Yorkshire Railway, and the London, Brighton, and South Coast Railway all have electrified sections in regular operation.

Electrified Body, Energy of. See ENERGY OF AN ELECTRIFIED BODY.

Electrocapillarity.—If two liquids are in contact, a gradient of electrical potential usually alters the surface-tension between them. Thus the surface of mercury in a fine tube moves quite appreciably when in contact with weak sulphuric acid, if a pressure be applied to them. Lippmann's electrometer (see ELECTROMETER), which is very sensitive to small pressures, is constructed on this principle.

Electrochemical Equivalent. See ELECTROLYSIS.

Electrochemical Series. See ELECTROLYSIS.

Electrochemistry. — *Electrochemistry* is the term applied to that branch of chemistry in which chemical changes and combinations are effected by the aid of electricity.

Electrochemistry may be divided broadly into two branches, firstly, that in which the changes effected are truly electrochemical, being obtained by *electrolysis* (which see), and secondly, that in which the changes are effected by heat, the heat being generated by the passage of current either through the material or through conductors adjacent to the material. See FURNACE, ELECTRIC; ELECTROMETALLURGY.

Electrode.—

['*Electrode*, a conductor by which an electric current passes into or out of an electrolytic or other substance.'—I.E.C.]

See ELECTROLYSIS.

Electrodeposition. See ELECTROMETALLURGY.

Electrodynamic, pertaining to the forces acting between current-carrying conductors.

Electrodynamic Attraction and Repulsion, the forces with which current-carrying conductors act upon one another. The real actions between conductors forming portions of a circuit cannot be determined, as our experiments are necessarily made with complete circuits (see 'Electricity and Magnetism', § 526, Maxwell). We may, however, say of two circuits that each tends to move so as to enclose as many as possible of the lines of force of the other, and each part of a circuit tends to move so that its circuit encloses a maximum number of lines of force, whether due to its own or to some other current. It will be seen that the action is a particular case of the forces exerted by a magnetic field on a current-carrying conductor. The so-called laws of electrodynamic attraction are again particular cases of this action, as applied to portions of the circuit which are near together compared with the remaining portions. [F. W. C.]

Electrodynamometer. See DYNAMOMETER; DYNAMOMETER, SIEMENS; DYNAMOMETER, WEBER ELECTRO-; WATTMETER; AMMETER.

Electro-enamel (Electro - émaille), the trade name of the first material introduced for heat-dissipating impregnating purposes. It renders the cotton covering tougher and more moisture-proof, but has relatively low dielectric strength. Another material with analogous properties is exploited under the trade name of BERRITE (which see). (Ref. 'The Insulation of Electric Machines', chap. ix, Turner and Hobart.) See also HEAT-DISSIPATING IMPREGNATING MATERIALS.

Electrogalvanising. See ELECTROMETALLURGY.

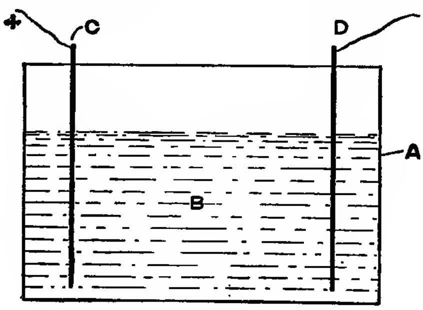
Electrogoniometer, an apparatus, devised by Gramont and Routin, which indicates the phase difference between two emf. It is suitable for pf measurements on a balanced three-phase load. The apparatus is described on pp. 173–192 of the 'Bulletin de la Société Internationale des Électriciens' for March, 1904. See also INDICATOR, PHASE OR POWER FACTOR.

Electrokinematics, the portion of the study of electricity which deals with electricity in motion, or with electric currents. See ELECTROSTATICS; ELECTROMAGNETISM.

Electrolysis.—*Electrolysis* or *electric analysis* was the term applied by Faraday to the process of decomposing a liquid by the passage of a current of electricity through it.

['*Electrolysis*, the passage of an electric current through an electrolyte.'—I.E.C.]

The vessel containing the liquid is known as an *electrolytic cell.* In the illustration A is



Electrolytic Cell

the cell, which may be of glass or of any other suitable material, and B is the liquid which is to be electrolysed. Current enters by the *positive electrode* C, also known as the *anode*, traverses the liquid, and leaves by the *negative electrode*, or *cathode*, D.

The passage of current through water splits up the molecules of water into their constituent atoms of oxygen and hydrogen, the former being given off in bubbles at the anode, and the latter at the cathode.

When current is passed through a solution of copper sulphate between platinum electrodes, the liquid is decomposed, atoms of copper being deposited at the cathode, bubbles of oxygen being given off at the anode, and sulphuric acid being formed in the liquid, which latter becomes more and more acid as the copper is withdrawn. If, however, the anode be of copper instead of consisting of platinum, sulphuric acid will not be formed, nor will oxygen be given off at the anode. As copper is deposited at the cathode, an equal quantity will be dissolved at the anode, so that the original constitution of the liquid is maintained.

The atoms separated from each other by the electric current were called *ions* by Faraday; those going to the anode being *anions*, and those going to the cathode being *kathions.* See also IONISATION.

Anions are generally regarded as *electronegative,* because they move as if attracted to the positive electrode, while kathions are regarded as *electropositive.*

In order to explain the transfer of electricity and the transfer of matter through the electrolyte, Grotthuss put forward the hypothesis that when two metal plates at different potentials are placed in a cell, the effect produced in the liquid is that the molecules of the liquid arrange themselves in innumerable chains, in which every molecule has its atoms pointing in a certain direction, the electropositive atom being attracted towards the cathode and the electronegative towards the anode. An interchange then takes place all along the line, the free atoms appearing at the electrodes, and every atom discharging a minute charge of electricity upon the electrode at which it is liberated.

An ELECTROCHEMICAL SERIES is an arrangement of the metals in a series in such a manner that the most electropositive is at one end and the most electronegative at the other. The order of the metals varies with the electrolyte in which the metals are tested. The following table shows such series for the most common metals, in three different solutions:—

Dilute Sulphuric Acid.	Dilute Hydrochloric Acid.	Caustic Potash.
Zinc	Zinc	Zinc
Cadmium	Cadmium	Tin
Tin	Tin	Cadmium
Lead	Lead	Antimony
Iron	Iron	Lead
Nickel	Copper	Bismuth
Bismuth	Bismuth	Iron
Antimony	Nickel	Copper
Copper	Silver	Nickel
Silver	Antimony	Silver
Gold		
Platinum		

If any metal is connected with any other in the list, a current will flow from the upper one to the lower one in the electrolyte, and from the lower to the upper in the external circuit.

ELECTROCHEMICAL EQUIVALENTS. — The general laws of electrolysis may be found in any work on electrochemistry, and are too numerous to be given in detail here. The most important law is that the amount of an ion liberated at an electrode in 1 sec is equal to the strength of the current multiplied by the electrochemical equivalent of the ion. It has been found by experiment that a current of 1 amp liberates 0·00001035 g of hydrogen per sec.

Thus the weight of a substance liberated or decomposed by an electric current is equal to the strength of the current in amp multiplied by the time in sec, and by the electrochemical equivalent. 1 coulomb of electricity (= 1 amp flowing for 1 sec) will liberate 0·00001035 g of hydrogen. To find the amount of any other element liberated or decomposed, this figure must be multiplied by the atomic weight of the element and divided by the valency of the element. The following table shows the electrochemical equivalent of some of the principal elements:—

Element.	Electrochemical Equivalent.
Hydrogen	0·00001035 (g per coulomb)
Gold	0·0006780 ,,
Silver	0·0011180 ,,
Copper (cupric)	0·0003261 ,,
,, (cuprous)	0·0006522 ,,
Iron (ferric)	0·0001932 ,,
,, (ferrous)	0·0002898 ,,
Nickel	0·0003054 ,,
Oxygen	0·0000828 ,,
Chlorine	0·0003675 ,,
Nitrogen	0·0000445 ,,

The passage of current through an electrolyte depends partly upon its ohmic resistance and partly upon its emf of polarisation. The emf of polarisation may be defined as the emf necessary to split up the molecules into their constituent atoms.

In order that conduction of current through an electrolyte may take place continuously, it is necessary that the emf at the electrodes shall exceed the emf of polarisation. If, however, the applied emf is less than this, a feeble current will flow for a short time until the opposing emf has reached an equal value. To this phenomenon the term *electrolytic convection* has been applied.

In most electrolytic processes, it is important, in order to get the best results, that the liquid should be maintained at a given density, *i.e.* specific gravity. The most convenient means of measuring the density is by means of a hydrometer graduated to read specific gravity direct. See HYDROMETER; HYDROMETER SCALES.

In some cases solids other than metals become decomposed by the passage of a current, and are on this account classed as solid electrolytes. See ELECTROMETALLURGY; GALVANIT. [C. W. H.]

Electrolysis, Counter Electromotive Force of. See ELECTROMOTIVE FORCE, COUNTER.

Electrolyte.—

['*Electrolyte*, any substance which undergoes chemical decomposition by the direct action of an electric current passing through it.'—I.E.C.]

['The solid or fluid mass through which the current passes between anode and cathode. The electrolyte must be capable of electrolytic decomposition, and therefore it must be a chemical compound.'—'Electrometallurgy', Kershaw.]

See ELECTROLYSIS.

Electrolyte, Density of. See ELECTROLYSIS.

Electrolytic Bleach, a bleaching agent produced by the passage of current through a suitable electrolyte. Thus a strong bleaching and disinfecting solution may be obtained by the passage of current through sea water or through a solution of magnesium chloride.

Electrolytic Cell. See ELECTROLYSIS.

Electrolytic Condenser. See CONDENSER, ELECTRIC.

Electrolytic Convection. See ELECTROLYSIS.

Electrolytic Detector, an instrument employed for the purpose of indicating the presence and direction of an emf between any two points. The instrument generally consists of two electrodes immersed in a solution of phenolphthalein or other chemical indicator, and when connected it shows, by a coloration of the solution at one pole, which terminal is positive and which is negative.

Electrolytic Engraving of Metals. See Electrometallurgy.

Electrolytic Interrupter. See Rectifier; Interrupter, Simon; Interrupter, Wehnelt; Automatic Interrupter.

Electrolytic Lightning Arrester. See Lightning Arrester.

Electrolytic Meter. See Meter, Electrolytic.

Electrolytic Process, any process which is accomplished by the passage of current through an electrolyte. See Electrolysis; Electrochemistry; Electrometallurgy.

Electrolytic Rectifier. See Rectifier.

Electrolytic Treatment of Copper. See Electrometallurgy.

Electrolytic Valve. See Rectifier.

Electromagnet, a magnet consisting of soft iron or mild steel around which is wound a coil for carrying current and magnetising the iron.

['*Electromagnet.*—An electromagnet is one in which the magnetic field is produced by an electric current.' —From 'Electrical Handbook', 1908, p. 201, McGraw.]

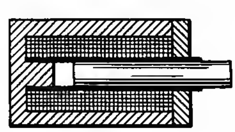
Electromagnet, Annular. See Magnet, Ring.

Electromagnet, Bar. See Bar Electromagnet.

Electromagnet, Differential, a magnet having two or more windings so arranged as to magnetise in opposition, so that the pull of the magnet depends upon the difference between the two currents. Differential magnets are generally used to operate some mechanism or contact, whenever the difference between the pressure from two sources exceeds a predetermined amount.

Electromagnet, Interlocking. See Interlocking Electromagnet.

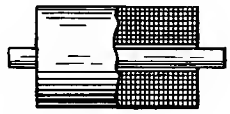
Electromagnet, Ironclad, an electromagnet consisting of a coil and core in which the magnetic circuit is partly completed by means of an external sheath of soft iron (see fig.).



Ironclad Plunger Electromagnet

Electromagnet, Long-range. See Magnet, Long-pull.

Electromagnet, Plunger, an electromagnet whose core, or a portion of whose core, is mounted so that it can be drawn into the coil when the latter is excited. The fig. shows a simple plunger electromagnet, while the illustration accompanying the definition of *electromagnet, ironclad,* shows a plunger electromagnet of the ironclad type.



Plunger Electromagnet

['*Electromagnet, plunger.*—An ironclad plunger magnet is a plunger magnet placed in a protecting shell, which also forms a path for the flux.'—From 'Electrical Handbook', 1908, p. 201, McGraw.]

['A plunger magnet is a solenoid fitted with a movable core.'—From 'Electrical Handbook', 1908, p. 201, McGraw.]

Electromagnet, Polarised, an electromagnet to which a constant magnetising force is applied, in addition to a variable one. The object is usually to keep the magnet in its state of greatest sensitiveness to change in the variable component. Polarised electromagnets are used in relays for telegraphic and other purposes.

Electromagnet, Tractive. See Lifting Power of Magnet.

Electromagnet for Alternating Electricity, an electromagnet excited by alternating electricity. Such magnets require to be made with laminated iron cores in order to avoid eddy currents and to economically obtain a strong magnetic effect. The pull of an alternating electromagnet is intermittent. The magnetising component of the current taken by such a magnet is 90° out of phase with the applied terminal pressure.

Electromagnetic Ammeter. See Ammeter.

Electromagnetic Brake. See Brakes; Crane, Electric.

Electromagnetic Capacity. See Capacity, Electromagnetic.

Electromagnetic Control. See Control, Electromagnetic.

Electromagnetic Energy. See Energy.

Electromagnetic Field of Force. See Field of Force.

Electromagnetic Induction. See Induction; Induction, Electromagnetic.

Electromagnetic Inertia, a term expressing the fact that it requires energy to start an electric current in an inductive circuit, and an equal amount of energy to stop such a current. Such energy corresponds to the starting and stopping of a heavy mass. The inductance of a circuit is analogous to mass. Thus electromagnetic inertia is measured by $\frac{1}{2} l I^2$ or $\frac{1}{2}$ N I or $\int N\, d I$

where l = Inductance in henrys
N = Total linkage of flux and turns
I = Current in amp.

Electromagnetic Resonance. See RESONANCE, ELECTROMAGNETIC.

Electromagnetically Operated Switch. See SWITCH, ELECTROMAGNETICALLY OPERATED.

Electromagnetism, the branch of electrical science which deals with the connection between electric and magnetic phenomena. See ELECTROSTATICS; ELECTROKINEMATICS.

Electrometallurgy. — The science of electrometallurgy may be divided under four heads. (1) The reduction of metals direct from solutions of their ores. (2) Electroplating. (3) Production of stereotypes, medallions, &c., by electrodeposition. (4) Smelting and reduction of metals by the electric furnace.

ELECTRODEPOSITION.—Processes (2) and (3) are both accomplished by electrodeposition, *i.e.* by the deposition of metallic ions on a cathode in an electrolytic bath. See ELECTROLYSIS; GALVANIT.

ELECTROLYTIC TREATMENT OF COPPER.—One of the most important electrometallurgical processes is the electrolytic treatment of copper. Copper deposited from crude bars as anodes upon copper cathodes in a sulphate of copper solution possesses a purity unattainable by any other means. The electrolytic cell used for this purpose is known as a *copper bath.*

ELECTROLYTIC REFINING. — The process of thus obtaining pure metals by electrolytic treatment is known as *electrolytic refining,* and is applicable to copper, silver, and other metals.

ELECTROPLATING.—Electroplating consists in obtaining an electrodeposit of one metal, used as an anode, upon some metallic article which is connected to form the cathode in an electrolytic bath. Thus from a gold anode gold may be deposited upon a cathode of any inferior metal, in a bath of cyanide of gold; similarly, silver may be electrodeposited from a solution of cyanide of silver. Copper may generally be deposited from a solution of sulphate of copper, but, with an iron cathode, it is necessary to use a solution of cyanide of copper. Nickel is deposited from a solution of double sulphate of nickel and ammonium.

STRIPPING.—Metals of a like character do not adhere firmly to each other; thus electrodeposited gold will not adhere to a gold surface, and so on. Worn articles of electroplate, which are to be re-plated, require therefore to have the whole of the previous plating removed before receiving a new coat. This process of removal, which is accomplished by various acids, is technically known as *stripping.*

ELECTROGALVANISING. — The process of depositing zinc upon iron articles is known as *electrogalvanising,* and is largely taking the place of the old process of galvanising by dipping the articles in molten zinc.

ELECTROTYPE. — Stereotype plates and blocks for illlustrations, produced by electrodeposition, are known as *electrotypes.*

ELECTROLYTIC ENGRAVING OF METALS.—Metals to be engraved electrolytically are placed as anodes in an electrolytic bath. The surface of the metal is first covered with an insulating varnish, and the pattern required is scratched through the varnish. When placed in the bath and subjected to the current, that portion of the metal from which the varnish has been removed is eaten away, so that the pattern becomes engraved on the metal. See also FURNACE, ELECTRIC.

Electrometer, an instrument for measuring potential by the attraction or repulsion between the charges induced in its fixed and moving parts, by the potential to be measured.

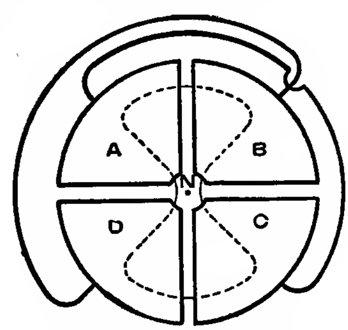


Fig. 1.—Quadrant Electrometer

QUADRANT ELECTROMETER.—This instrument, devised by Kelvin, consists of four quadrant-shaped boxes, A, B, C, D, containing a floating *needle,* N, attached to which is a mirror for reading the deflection. The quadrants are very carefully insulated with glass, paraffin wax, amber, or other material of this class, and opposite quadrants are connected together as shown in fig. 1. For methods of connecting, see HETEROSTATIC and IDIOSTATIC METHOD.

RECORDING ELECTROMETER.—Recording electrometers have been used by Kelvin and others in researches on atmospheric electricity. The various appliances usually depend on photography for obtaining a record.

LIPPMAN'S ELECTROMETER, an electrometer based on the principle of *electrocapillarity*. See 'Capillary Electrometer' below.

ELECTROMETER GAUGE, an attachment to Kelvin's electrometers for testing the potential of the needle when used heterostatically. In metallic contact with the needle is a horizontal insulated disk which attracts a small pivoted aluminium disk charged oppositely by induction.

The amount of the attraction obviously varies with the potential of the needle, and the position of the aluminium disk is read by means of a hair carried on a lever attached to it, and moving in front of two black dots. When the hair is seen between the dots, through a lens which is provided, the reading of the needle is correct.

ABSOLUTE ELECTROMETER, an instrument in which a charge of electricity is directly weighed against gravity. In Kelvin's form there are two aluminium disks, the lower one of which is fixed and the upper attached to the beam of a sensitive balance. The capacity of the instrument is calculated from its dimensions, and in order that the distribution of potential may be uniform, the movable disk is surrounded by a guard ring. See GUARD RING.

CAPILLARY ELECTROMETER.—This instrument depends on the circumstance that, if mercury and dilute acid are allowed to come into contact within a glass capillary tube, and if a current is passed through, the junction will tend to move to the negative end. Fig. 2 shows the arrangement of Dewar by which it is claimed that a potential of 0·003 volt may be measured. See ELECTROCAPILLARITY. [L. M.]

Fig. 2.—Capillary Electrometer

DOLEZALEK QUADRANT ELECTROMETER, a very sensitive form of the quadrant-type electrometer, made in accordance with the designs of Dolezalek (see fig. 3). The quadrants are of small dimensions, and are mounted upon ambroid. The moving parts are very light. The needle is also of small dimensions, and is of paper thinly coated with metal ('silver paper'). Owing to the smallness of both the needle and the quadrants, the electrostatic capacity is also small. The needle is suspended by a quartz fibre, and, owing to its lightness, great sensitiveness is secured. The needle is also, owing to its lightness, and the resistance offered to its movement by the air, almost dead-beat. The deflections are, throughout a wide range, proportional to the pressures producing them.

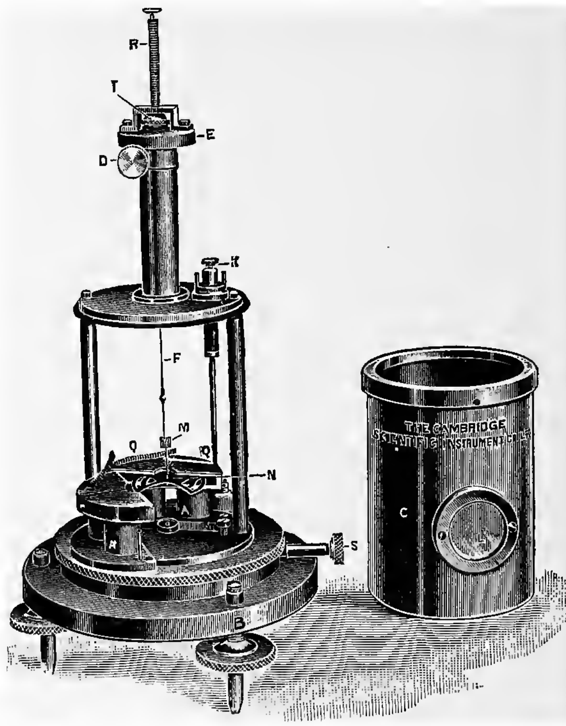


Fig. 3.—Dolezalek Quadrant Electrometer

AA, Ambroid insulator. B, Brass base. C, Brass cover. D, Clamping screw. E, Ebonite torsion head. F, Quartz fibre. K, Charging switch. L, Lens. M, Mirror. N, Paper needle. QQ, Four brass quadrants. R, Brass rod. S, Clamping screw. T, Adjusting nut.

The needle is charged by a special key, shown at K in fig. 3. This key consists of an insulated terminal with a brass rod projecting downwards, and carrying a light strip of phosphor bronze at its lower end, which can be brought into contact with the needle, and then withdrawn. The suspending fibre is provided with a hook at each end. These hooks engage with eyes upon the torsion head and needle respectively in such a way that no slip or backlash can be introduced. The entire instrument can be rotated in azimuth about its base, and clamped by the clamping screw S. In the fig. the front quadrants are shown swung open on their hinge to allow of easy access to the needle.

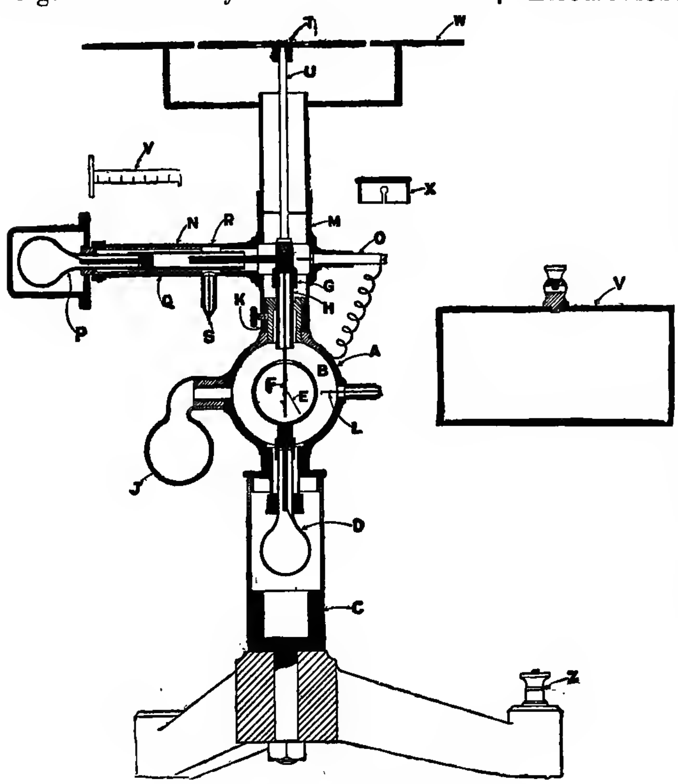


Fig. 4.—Universal Portable Electrometer

A, Earthed brass cylinder. B, Brass cylinder mounted on the top of the neck of quartz Leyden jar D. O, Supporting pedestal. E, Gold leaf. F, Brass wire supporting E. G, Brass socket. H, Quartz tube. J, Drying vessel. L, Platinum wire. M, N, Brass tube. O, Sliding rod, by means of which the gold-leaf system is earthed when desired. P, Quartz Leyden jar. Q, Brass tube. R, Rod. S, Platinum wire. T, Test plate. U, Brass rod. V, Brass cover for W. W, Guard plate. Z, Earth connection.

UNIVERSAL PORTABLE ELECTROMETER, a gold-leaf instrument designed especially for the measurement of pressures differing only slightly from zero as well as for higher pressures. The essential feature of the instrument is that the gold leaf hangs within an inner case (see fig. 4), which is maintained at a suitable pressure by means of a quartz Leyden jar. A compensator (shown to the left of the diagram) enables charges to be measured by a constant-pressure method. It consists of a cylindrical condenser, of which the inner conductor is a metal rod connected to the gold-leaf system, the outer conductor being a brass tube, maintained at a constant pressure by means of a second quartz Leyden jar, and capable of sliding parallel to its length to give a variable capacity. The apparatus as shown in fig. 4 was specially designed by C. T. R. Wilson for measurements in atmospheric electricity.

Electrometer Gauge. See ELECTROMETER.

Electromobile, any vehicle propelled by electric power derived from a source of electrical energy, such as a primary or secondary battery, carried by or contained within the vehicle itself; especially a vehicle adapted for traffic upon ordinary roads (see also ACCUMULATOR CAR).

'A generic word describing a car having the power of motion.' (Lord Halsbury, 'Elec. Eng.', Dec. 19, 1907, p. 960.)

Electromotive Force (preferable abbreviation, *emf*), that which causes or tends to cause an electric current. The expression, although sanctioned by usage, and having a perfectly definite connotation, is not scientifically accurate, as emf is not a force in the accepted meaning of the word (see FORCE). The real nature of emf is involved in that of electricity, but it must be conceived as acting on electricity and not on the bodies in which the electricity resides. (Ref. 'Electricity and Magnetism', §569, Maxwell.)

The expression is used in two distinct senses. It is primarily something which resides in certain regions of activity, such as voltaic cells, conductors moving relatively to magnetic fields, or the rubbing surfaces of dielectrics. It appertains, in fact, to the seat of energy conversion, and is one of the two elements whose product represents the electrical energy generated, the other being the electric displacement produced. On the other hand, the expression is used to designate the condition produced by some source of electromotive activity, tending to cause a flow of electricity from one point to another, the path between these points not including the elements of electromotive activity. In this sense it is the line integral of the electric force taken along a line joining the points (such line not passing through the source of activity), that is, the difference of potential between the points. It is, therefore, sometimes distinguished as *potential difference* or *pd.* Such an emf exists between a charged body and neighbouring bodies, or between points on a conductor carrying a steady current and at rest relatively to the surrounding magnetic field.

The chief sources of emf are chemical action in primary and secondary cells (see BATTERY, PRIMARY; ACCUMULATOR), and variation in magnetic flux through a circuit (see INDUCTION, ELECTROMAGNETIC). In the latter case the magnetic flux may be partly due to the current in the circuit considered, whose variation gives rise to an emf. See INDUCTION, SELF-.

Emf are additive, and the current produced in any conductor of a network is the algebraic sum of the currents that would be produced by the several emf which act in the network.

Emf is always measured as pd, and the practical unit of measurement is the volt (which see). [F. W. C.]

['*Electromotive Force*, that which causes or tends to cause an electric current.'—I.E.C.]

See also POTENTIAL, ELECTRIC; PRESSURE; VOLTAGE.

Electromotive Force, Applied. See ELECTROMOTIVE FORCE, IMPRESSED.

Electromotive Force, Component, a term applied to a component of an alternating emf wave. Such a wave, when represented by a rotating vector, may be split up into any number of components which have as their resultant the total emf wave. For instance, if a current flows through a reactance and a resistance placed in series, the total emf drop will be the resultant of the two component emf (due to reactance and resistance) combined at right angles.

Electromotive Force, Counter, an emf in any circuit whose direction is opposed to that of the current in the circuit. The existence of a c emf implies the absorption of electric energy. Thus we speak of the c emf of a motor or of a secondary battery which is being charged. The expression is appropriately abbreviated to *c emf.* The term *c emf* denotes the emf induced in a motor or transformer, which balances the impressed emf. At no-load the c emf is due to the induced emf only, as there is practically no resistance drop, but when load current flows the c emf is the sum of the induced and resistance emf. Hence, strictly speaking, the c emf is always equal and opposite to the impressed emf, though the term is frequently used to denote the induced emf only.

COUNTER EMF OF SELF-INDUCTION, a c emf self-induced by variation of the magnetic field produced by the current occasioned by the impressed emf.

COUNTER EMF OF MOTOR, the c emf induced in the armature of a motor by reason of its rotation in a magnetic field.

COUNTER EMF OF POLARISATION.—In the electrolysis of water, bubbles of gas collect on the electrodes and give rise to an emf between themselves, which is opposite in direction to the impressed emf. This emf is called the *emf of polarisation,* and would be capable of maintaining a current for a short time, if the electrodes were temporarily disconnected from the battery and connected together. In a simple galvanic couple, such as zinc and copper in sulphuric acid, the c emf of polarisation, due to the hydrogen bubbles collecting on the copper, is sufficient to diminish greatly the useful emf of the couple. In primary cells, which are mainly variations of this simple couple, various methods are employed to eliminate polarisation. See DEPOLARISE; BATTERY, PRIMARY.

COUNTER EMF OF ELECTROLYSIS, the minimum emf at which electrolysis will take place. For example, water requires an emf of 1·48 volts to dissociate it into hydrogen and oxygen. This constitutes the c emf of electrolysis of water. See also 'Counter emf of the Arc' under ARC.

Electromotive Force, Effective, synonymous with *rms emf.* See ROOT MEAN SQUARE.

Electromotive Force, Impressed (sometimes termed *applied electromotive force* or *applied pressure*), denotes the external emf acting on a conductor or circuit. For example, the impressed emf of a motor is the emf at its terminals, *i.e.* the emf of the mains to which it is connected. Corresponding to the impressed emf there is always a back emf which is equal and opposite to it, whether produced by resistance, reactance, capacity, or the motion of conductors in a magnetic field.

Electromotive Force, Induced, an emf produced in a circuit by variation in the magnetic induction linked with the circuit.

In a coil of wire of T turns, each of which is traversed by an average of M lines of magnetic induction, the induced emf is:

$$e = T \times \frac{dM}{dt} \times 10^{-8} \text{ volts.}$$

Where the flux M is alternating, and has a maximum value M_0, the rms pressure induced, *i.e.* the back pressure, is (in the case of sine waves of pressure),

$$E = \frac{2 \times \pi \times \sim \times T \times M_0 \times 10^{-8}}{\sqrt{2}} \text{ volts}$$

$$= 4{\cdot}44 \times \sim \times T \times M_0 \times 10^{-8} \text{ volts.}$$

See also CUTTING LINES OF MAGNETIC FORCE.

Electromotive Force, Resultant, the emf which is the combined effect of two or more emf.

Electromotive Force, Rotation, that component of the emf due to relative motion of the conductors and the magnetic field, as distinguished from that component due to alternations of the field strength.

Electromotive Force, Sinusoidal Alternating, an emf varying according to a sine law. See SINE WAVE EMF OR CURRENT.

Electromotive Force, Transformer. If a cc armature is placed in an alternating magnetic field, an emf will be set up in its windings, even when the armature is at rest. This is termed the *transformer emf.*

When the armature is revolved, another emf is set up which is proportional to the speed, and this is termed the *speed emf.* The two emf are in time quadrature.

Electromotive Force, Unit of. See VOLT.

Electromotive Force Curve. See CURVE, CHARACTERISTIC.

Electromotor, a dynamo-electric machine which receives electric power from an external source, and converts it into mechanical power, for driving machinery; also called *electric motor.* See MOTOR, and definitions of various types of motors.

Electronegative. See ELECTROLYSIS.

Electrophorus, a simple type of electric induction machine by which a series of electric charges may be obtained by induction from a single charge produced by friction on an ebonite or resin plate. The apparatus consists of the resin plate in a metal dish and a metal plate with an insulating handle. After the resin has been electrified by rubbing with fur or wool, the metal plate is placed on it and connected momentarily to the dish. If the connection is then broken and the plate lifted, it will be found that it has become charged.

Electroplating. See ELECTROMETALLURGY.

Electroplating Dynamo, a continuous-electricity generator specially designed to give out a large current at a l pr (usually not more than five volts), for depositing metals out of their solutions, and either shunt-wound or separately-excited, to prevent reversal of the polarity of the machine. See GENERATOR.

Electropneumatic Signal. See SIGNAL, ELECTROPNEUMATIC.

Electropneumatic Traction System. See ARNOLD SINGLE-PHASE ELECTROPNEUMATIC TRACTION SYSTEM.

Electropneumatically-controlled Unit Switch. See SWITCH, ELECTROPNEUMATICALLY-CONTROLLED, UNIT.

Electropositive. See ELECTROLYSIS.

Electrorefining of Metals. See ELECTROMETALLURGY.

Electroscope, an instrument for detecting the presence of an electrical charge.

PITH-BALL ELECTROSCOPE.—The simplest form is that known as the *pith-ball electroscope,* which consists of a small ball of dry pith (usually about ½ cm diameter), preferably coated with gold leaf, and hung from an insulating support by a dry silk thread. On bringing a charged body near the pith ball, it is attracted, but after making contact it is repelled.

GOLD-LEAF ELECTROSCOPE.—The *gold-leaf electroscope* consists of two small strips of gold leaf (usually about 5 cm long and 1 cm wide), attached at the same point to a metal support, and hung up in a glass case in such a way that the support is perfectly insulated and may receive a charge. It will be found that when charged, the leaves repel each other, owing to the repulsion between charges of like sign.

CONDENSING ELECTROSCOPE.—The *condensing electroscope* (see fig. 1) consists of a gold-leaf electroscope combined with a simple

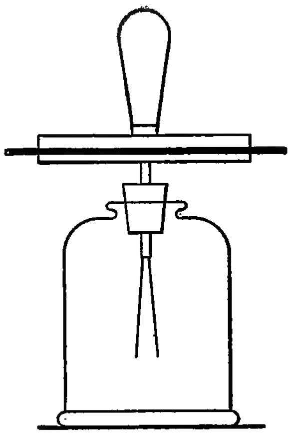


Fig. 1.—Condensing Electroscope

condenser, which usually takes the form of two brass disks separated by a very thin layer of insulation. If a charge of low potential is given to such an arrangement, the leaves will diverge after the plates have been separated, since an increase of potential will result from the decrease of capacity of the condenser. Charges may be detected in this way, which are so small that they would give no effect on the gold-leaf electroscope alone.

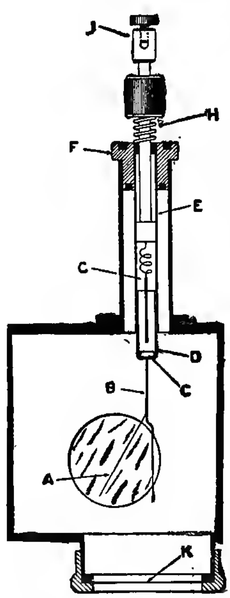


Fig. 2.—Simple Micro-electroscope

A, Gold leaf. B, Supporting wire. C, Metal plug supporting B. D, Quartz tube. E, Brass tube. F, Ebonite bushing. G, Wire attached to spring. H, Spring. J, Terminal wire. K, Paper diaphragm.

SIMPLE MICRO-ELECTROSCOPE, a gold-leaf electroscope in which only a single movable leaf is employed, repulsion taking place between this and a prolongation of the wire which supports it. It is especially adapted for experiments on ionisation and radio-activity. An opening in the case (see fig. 2) vertically beneath the gold leaf, enables the ionising agent to exert its influence upon the air within the electroscope case, and openings at the side are provided for viewing the gold leaf. High insulation is obtained in the design shown in fig. 2 by the use of quartz. A simple charging device is used which may either be connected to the gold leaf momentarily or permanently.

There are two methods of observing the deflections of the gold leaf: (1) A microscope with micrometer eyepiece is used. (2) The deflections are read off without magnification against the reflected image of a mm scale. For this purpose a scale is mounted on a sliding arm a few cm in front of the inspection-window, the lower half of which is silvered, and therefore reflects the scale. An observer looking into the window therefore sees coincidently with the gold leaf, the virtual image of a scale external to the electroscope. This arrangement of the scale avoids all errors due to parallax.

Electrostatic, an adjective indicating that the electricity is at rest. It is also used, though incorrectly, to describe electricity generators which depend on variation of capacity. See MACHINE, WIMSHURST; ELECTROSTATIC INDUCTION MACHINE.

Electrostatic Attraction and Repulsion, forces due to the mutual action of electric charges. This was the earliest form of electrical action observed. Like all other forces which may be assumed to act from a point, these vary inversely as the square of the distance.

Electrostatic Capacity. See CAPACITY, ELECTROSTATIC.

Electrostatic Effects, effects due to static charges of electricity. These are usually only noticeable when the pressure is very high.

Electrostatic Field, a region in which there is steady electric force. *The field* is sometimes used to indicate the intensity of the force. See FIELD OF FORCE.

Electrostatic Induction. See INDUCTION; INDUCTION, ELECTROSTATIC.

Electrostatic Induction, Coefficient of. See DIELECTRIC CONSTANT.

Electrostatic Induction Machine, an electricity generator which acts by variation of capacity, as the ordinary dynamo acts by variation of inductance. Such machines are useful for the production of very h pr, but they give very little current. The chief types are the Wimshurst, Voss, Holtz, and

Toepler-Holtz. These all produce unidirectional current. The largest machine so far constructed is Lord Blythswood's Wimshurst, which has 48 plates 3 ft in diameter, and requires about 3 hp to drive it. See MACHINE, WIMSHURST. [J. E-M.]

Electrostatic Lines of Force. See LINE OF INDUCTION.

Electrostatic Ohmmeter. See OHMMETER.

Electrostatic Process of Ore Separation. See SEPARATION OF ORES.

Electrostatic Refraction, bending of the lines of electric force on entering a medium with a different dielectric constant.

Electrostatic Shield. See SHIELDING OF ELECTRICAL MEASURING INSTRUMENTS.

Electrostatic Stress. See STRESS, ELECTRIC.

Electrostatic Voltmeter. See VOLTMETER.

Electrostatic Wattmeter. See WATTMETER.

Electrostatics, the portion of the study of electricity which deals with charges of electricity, or with electricity at rest. See ELECTROKINEMATICS; ELECTROMAGNETISM; ELECTRICITY.

Electrothermic Process, a process which depends on the combined action of electricity and heat.

Electrotype. See ELECTROMETALLURGY.

Element, Thermo-electric, a circuit composed of (at least) two different metals. Among the commoner metals, bismuth and antimony give the greatest effects. In order to produce a current, one junction of the metals must be at a different temperature from the other junction. The emf generated is usually equal to the product of two factors, one being the difference of temperature of the junctions, and the other the difference of the electric heights of the two metals at the average temperature. (Ref. 'Units and Physical Constants', Everett.) See CURRENT, THERMO-ELECTRIC.

Element of Accumulator Cell. See CELL, ACCUMULATOR, ELEMENT OF.

Elements, Electrical Classification of. See 'Electrochemical Series' under ELECTROLYSIS.

Elliptic Rotating Field. See FIELD, ROTATING.

Embedded Length of Winding, that portion of the winding which actually lies in the slot, and is therefore embedded in iron. The remainder of the winding, such as the end-connections and that portion which crosses ventilating ducts, and is therefore surrounded by air, is called the *free length of winding.*

Emergency Brake, a brake of any description with which a car or train is equipped for use only in case of sudden emergency, requiring a quick stop. See also BRAKES.

Emergency Switch. See SWITCH, EMERGENCY.

Emergency Wagon, a wagon hauled by horses, or propelled by a petrol motor, and equipped with a scaffold or ladders, tools, &c., in readiness to proceed, with the minimum delay, to the scene of a breakdown on an electric tramway, and to effect the necessary repairs.

Emf, the preferable abbreviation for *electromotive force* (which see).

Emissivity (heat). See HEAT-DISSIPATING IMPREGNATING MATERIALS; ELECTRO-ENAMEL; BERRITE.

Emissivity (light).—The sense in which emissivity is generally used in electrical literature is as follows. If two bodies, A and B (neither having the property of selective radiation), have the same surface temperature, and if A gives out more light per unit area than B, its emissivity is said to be greater. In this sense emissivity is a function of the chemical composition of the material, and of the nature of its surface (rough, smooth, polished, &c). The term is also used in connection with such cases of selective radiation as the incandescent gas mantle, in which (without altering the surface temperature) a small addition of ceria greatly increases the amount of light emitted. The *emissivity* in this case is said to be increased.

Empire Cloth, the trade name of cambric impregnated with linseed oil by a process the precise details of which vary with the manufacturer, and are kept more or less secret. Empire cloth is uniform in thickness, is flexible, and has good dielectric strength. It is manufactured in thicknesses ranging from 0·007 to 0·015 in (0·18 to 0·38 mm), and is supplied in rolls. It is extensively used for the insulation of armature and transformer coils.

Enamel, Electro-. See ELECTRO-ENAMEL.

Enamel as an Insulator.—*Enamel* is

the term often applied to a varnish with which a mineral pigment has been intimately mixed. Enamels are not extensively used for insulating purposes, since their dielectric strength is low, but they give a highly finished surface that wears well. See also ENAMELLED SLATE.

Enamel-insulated Wire. See WIRE, ENAMEL-INSULATED; WIRE, MAGNET; ENAMELLED COPPER WIRE.

Enamel Rheostat. See RHEOSTAT.

Enamelled Copper Wire, copper wire insulated with a thin uniform covering of enamel. The enamel has a higher dielectric strength, is more moisture-proof, and yields a thinner covering than cotton, which is of importance in winding coils of many turns. See WIRE, ENAMEL-INSULATED; WIRE, MAGNET.

Enamelled Magnet Wire. See WIRE, MAGNET; WIRE, ENAMEL-INSULATED; ENAMELLED COPPER WIRE.

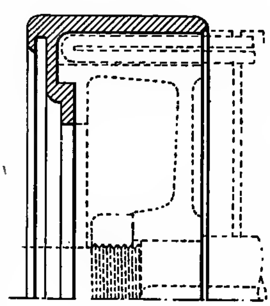
Enamelled Pressed Stranded Cable. See CABLE, PRESSED STRANDED.

Enamelled Slate.—When slate is used for switchboards or rheostat faces, it is usual practice to enamel the surface with a hard black enamel. This gives a more handsome appearance, and prevents the absorption of moisture. See also SLATE AS AN INSULATING MATERIAL; ENAMEL AS AN INSULATOR.

Enamelled Wire. See ENAMELLED COPPER WIRE; WIRE, ENAMEL-INSULATED; WIRE, MAGNET.

Enclosed Arc Lamp. See LAMP, ARC.

End Bell, a metal casing for covering in and holding down the end connections of high-speed electric machines. An instance of this construction is given in the fig., in which the shaft, the spider, and the end connections are indicated by the dotted lines, and the end bell by the full lines.



End Bell

End Cells of an Accumulator. See ACCUMULATOR, END CELLS OF.

End Connections, those parts of armature (or alternator) windings which never cut magnetic lines of force. They join together two parts of the winding which do cut such lines. See also HOBART TYPE OF END CONNECTION; 'Eickemeyer Coil' under COIL, FORM-WOUND.

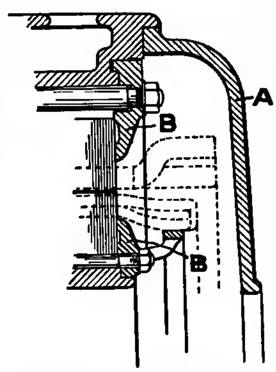
End Connectors. See END CONNECTIONS.

End-gap Static. This term is defined by Creighton (A.I.E.E., vol. xxvi, part ii, p. 1060), as follows:—

'*End-gap Static,* discharges of a multigap arrester. On high-potential circuits a few of the series gaps at each line connection are bridged by tiny sparks which give out a buzzing sound. The number of gaps bridged by the sparks depends on several factors—applied potential, relative capacity of each cylinder to its adjacent cylinder and ground, and leakage through or over the surface of the supporting porcelain.'

End Leakage, magnetic leakage at the ends of the armature or other member of a dynamo-electric machine. See 'Flank Dispersion' under DISPERSION, MAGNETIC.

End Plates, the cast-iron flanges against which the core stampings of an induction motor, an alternator, or of some other type of dynamo-electric machine are assembled, and which afford support to them against side buckling. In the fig. the end plates are shown at B. The end connections of the windings are protected by the end shield A. See CORE HEADS.



A, End shield. B, End plates

End Play, the latitude allowed to any revolving member to move longitudinally. The end play is usually limited by fixing on the spindle collars which come up against the fixed bushes. The total distance between these collars and the bushes (at both ends) is equal to the amount of end play.

End-play Device, a contrivance fitted to the end of one of the bearings of a motor or of a rotary converter, which causes the rotating part to move backwards and forwards by the amount of end play provided.

A common type consists essentially of an eccentric-thrust bearing, set with balls to reduce the wear and the liability of seizing, and is used specially on rotary converters and motor generator sets, for which the speed of rotation is usually high. Its two functions are to prevent the brushes from wearing into hollows in the commutator and slip rings, and to facilitate an efficient supply of oil to all parts of the bearings.

End Rings, Commutator. See RINGS, COMMUTATOR.

End Shields.—Light, quadrant-shaped castings, which are bolted to the frame of an alternator or induction motor, and which, besides giving mechanical protection to the windings, prevent attendants from coming into accidental contact with the live parts of the machine when at work. Wherever possible, the castings should be of open pattern, in order to provide a free escape for the hot air from the stator coils. In machines of medium size the end shields are often extended and have the bearings cast in with them, as a machine of this type is more convenient to erect than one with pedestal bearings. In the fig. illustrating END PLATES, an end shield is indicated at A.

End Thrust, the force tending to move the armature, or other rotating part, longitudinally, so as to take up all the end play at one end of the machine. In dynamo-electric machines the end thrust may be due to the belt or gearing which the machine is driving, or it may be due to magnetic pull, if the revolving part is not accurately centred so as to be symmetrically placed in the magnetic field. See FIELD, DRAG OF.

Endruweit Brushes. See BRUSHES.

Energisation, a term which has been employed to denote the putting into action of electromagnetic apparatus by switching it into circuit.

Energy, a physical conception expressing the capacity of a system for doing work (see UNIT OF WORK). When work is done, energy is transformed from one form to another, the amount of energy so transformed being measured by the work done.

Whilst originally used in connection with the patent forces of dynamics, the meaning of the term has been extended to include all forms of natural activity which are capable of being transformed into mechanical work, either directly or indirectly. *Mechanical* energy exists in the form of *kinetic energy* wherever ponderable bodies are in motion, and in the form of *potential energy* in a stressed spring or raised weight. *Atomic* or *chemical energy* is the intrinsic energy of molecules, and an equivalent is absorbed or given out whenever chemical change takes place. *Molecular energy* is the energy of molecules as parts of a body, and may be potential, as the energy of stress, or kinetic, as the energy of heat. *Thermal energy* or sensible heat is really the kinetic energy of molecules. Light, radiant heat, and electric waves are forms of radiant energy differing only in degree. *Electric energy* makes itself manifest whenever electricity passes from a position of higher to a position of lower potential (see ELECTRICITY; ELECTROMOTIVE FORCE; POTENTIAL). *Electromagnetic energy* is the energy of an electric current due to a magnetic field which it surrounds.

It will be seen that the term *energy* implies a reference to a standard state. Thus, the kinetic energy of a projectile usually means the energy due to its velocity relatively to the earth, and not that due to its velocity in space. Electric energy exists, not because a charge of electricity is at a certain potential, but because it is at a potential differing from some neighbouring potential. Energy is only available for transformation into work when it exists in a system differing from surrounding systems.

The several kinds of energy are not independent, but may be differently described according to the point of view. Thus, the energy of a compressed gas is actually kinetic energy of the molecules. It may, however, be described as molecular energy, or, if the body of gas be considered as a whole, as potential energy.

The great importance of the conception of energy in its extended sense arises from the fact that experience has indicated two natural laws to which it is subject, and which are of great value as a basis for physical reasoning. The first of these, known as the *Principle of the Conservation of Energy*, asserts that the energy of a system is not increased or diminished by any action between the members of the system, or, briefly, that energy is indestructible. The second, known as the *Principle of the Degradation of Energy*, asserts that the tendency of natural processes is to cause energy to pass from the more available to the less available forms. Thus, although the amount of energy in the universe is unchangeable it is constantly becoming degraded towards the final level in which it will be unavailable. [F. W. C.]

As commercial unit of energy, the kelvin (which see) (equal to 1 kw hr) is the most convenient for electrical engineers.

$$1 \text{ kelvin} = 860 \text{ kg cal} = 367{,}000 \text{ kg m} = 3{,}600{,}000 \text{ joules} = 3\cdot 6 \times 10^{13} \text{ ergs.}$$

Energy, Conservation of. See ENERGY.

Energy, Convertible, of Steam.—To make steam of a given pressure and temperature out of water which is initially at 0° C., a certain definite quantity of energy must be imparted to the water. Thus, to convert a ton of water, whose initial temperature is 0° C., into steam of a pressure of 7 metric atm, and of a temperature of 214° C. (*i.e.* with 50° C. of superheat) 800 kelvins must be absorbed. The number of kelvins which, at 100 per cent thermodynamic efficiency (see under EFFICIENCY), can be converted into electricity is a function of the exhaust pressure, as also of the temperature and pressure of the steam. Thus, while if the exhaust pressure is 0·10 kg per sq cm, 188 kelvins of electricity may be obtained (*i.e.* 23·5 per cent of the energy absorbed in raising the steam), only 163 kelvins (*i.e.* only 20·4 per cent) can be converted into electricity if the exhaust pressure is 0·20 kg per sq cm. The amount of energy which, assuming 100 per cent thermodynamic efficiency, can be converted into work or electricity, as the case may be, is termed the *convertible energy of the steam.* Of course the thermodynamic efficiency falls considerably short of 100 per cent; consequently still smaller percentages of the energy originally absorbed are, with our present knowledge, capable of being converted into work or electricity.

Energy, Degradation of. See ENERGY.

Energy, Electric Transmission of, the transmission of energy from one place to another by means of electricity passing along electrical conductors that extend between the two places. (Ref. 'Electric Power Transmission', Louis Bell; 'Electrical Transmission of Energy', A. V. Abbott; 'Long Distance Electric Power Transmission', Hutchinson.)

Energy, Kinetic, the energy possessed by a body in virtue of its motion. A body of mass M moving with velocity V has a kinetic energy of $\frac{1}{2}MV^2$ units. The energy stored in the magnetic field surrounding a current is analogous to the kinetic energy of a moving mass. A current I, flowing in a circuit of inductance l, has a kinetic energy of $\frac{1}{2}lI^2$ units. This energy is expended in the form of heat when the circuit is broken.

The *surges* and *oscillations* experienced in connection with transmission lines consist of rapid conversions of the energy of a charge from kinetic to potential, and vice versa, until the energy is dissipated by resistance. See also ENERGY; ENERGY, POTENTIAL.

[R. C.]

Energy, Kinetic, of Armature, the mechanical energy stored in a rotating armature in virtue of its rotation as a flywheel, and apart from any store of energy which may exist, due to its electric or magnetic condition. The armatures of tramway and railway motors have sufficient kinetic energy to increase by some 10 per cent the momentum of the car or train. See COASTING; ANGULAR ACCELERATION OF CAR WHEELS; ENERGY, KINETIC; ENERGY, KINETIC, OF FLYWHEEL; ROTATIONAL ENERGY OF ARMATURE; FLYWHEEL STORAGE; STORAGE OF ENERGY.

Energy, Kinetic, of Flywheel, the mechanical energy stored in a rotating flywheel in virtue of its rotation. To impart a velocity V to a body of mass M, an expenditure of energy is necessary which is equal to $\frac{1}{2}MV^2$.

An equal amount of energy is theoretically recoverable on bringing the body to rest; consequently a body of mass M moving with a velocity V is said to have a store of kinetic energy of the above amount in virtue of its motion.

If a body, such as a flywheel, be rotating about an axis, different portions are moving with different velocities, and the kinetic energy is more conveniently expressed in the form $\frac{1}{2}I\alpha^2$, where I is the moment of inertia and α the angular velocity of rotation. A flywheel running at a speed of 1000 rpm, and with a diameter of gyration of 162·5 cm, has a kinetic energy of 1 kelvin per ton of weight. See FLYWHEEL STORAGE; STORAGE OF ENERGY.

Energy, Multiphase and Polyphase. See POLYPHASE POWER AND ENERGY.

Energy, Potential, the energy stored in a body by virtue of its position, or by its state of compression or tension. A weight raised from the earth contains potential energy. A charged condenser is a case often met with in electrical work, the potential energy stored in such a condenser being equal to $\frac{1}{2}KV^2$ units, where K is the capacity, and V the emf between the coatings. One ton at a height of 367 m has a potential energy of 1 kelvin. See ENERGY.

Energy, Rotational, of Armature. See ROTATIONAL ENERGY OF ARMATURE; ENERGY, KINETIC, OF ARMATURE.

Energy, Storage of. See STORAGE OF ENERGY.

Energy, Unit of. See ENERGY; KILOWATT-HOUR; KELVIN.

Energy Efficiency of an Accumulator. See ACCUMULATOR, EFFICIENCIES OF.

Energy Losses.—Whenever energy is transformed from one form to another, a loss necessarily accompanies the transformation, that is to say, the efficiency of transformation is always less than unity.

Thus, to convert electrical energy to mechanical energy we must expend part of the electrical energy in overcoming the resistances of the conducting circuit, in overcoming the resistance of air and journal friction, in changing the magnetic condition of the iron core, &c., and the sum of these losses constitutes the energy losses of the conversion. Consequently, at the pulley of the machine only part of the total energy supplied is available to do useful work.

The highest efficiency of transformation is probably reached by some dynamo-electric machines in the conversion of mechanical into electrical energy, while amongst the lowest is the conversion of mechanical energy into light within the visible spectrum.

ENERGY LOSSES IN SHEET IRON, the losses occurring through rapid reversal of magnetism. These are: (1) Hysteresis losses, (2) Eddy-current losses (see HYSTERESIS; LOSS, HYSTERESIS; EDDY CURRENT; LOSS, EDDY-CURRENT). The former are proportional to the frequency and the 1·5 or 1·6 power of the induction density limits, and the latter depend upon the square of frequency, induction density, and thickness of stampings, as well as on the specific conductivity of the material. See EFFICIENCY.

Energy Meter. See METER, ENERGY.

Energy of an Electrified Body, in electrostatics, one-half the value of the product of electric charge and electric potential. The energy thus depends, not only upon the amount of the charge concentrated upon the body, but also upon the potential of the body when in the charged state. It must also be remembered that the potential of the body will depend partly upon the presence of other charges of electricity upon other bodies which may be in the neighbourhood; further, that the seat of the energy is not in the body itself, but in the surrounding medium.

Engineering, Civil, 'the art of directing the great sources of power in nature for the use and convenience of man'. (From the 'Charter of the Institution of Civil Engineers'.)

Engineering, Electrical, those departments of civil engineering in which problems relating to electrical phenomena predominate.

Entz Booster. See BOOSTER; BOOSTER, REVERSIBLE.

Envelopes for the Plates of Accumulators. See ACCUMULATOR PLATES.

E.P.S. Accumulator. See 'Electrical Power Storage Accumulator' under ACCUMULATOR.

Epstein Hysteresis Tester. See TESTER, EPSTEIN HYSTERESIS.

Equaliser Switch. See SWITCH, EQUALISER.

Equalising Bars or Cables.—In order that compound-excited generators of continuous electricity may work in parallel, it

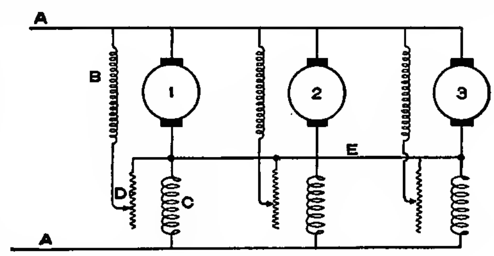


Fig. 1.—Equalising Bars or Cables

A, Bus-bars. B, Shunt spools. C, Series spools. D, Shunt rheostat. E, Equalising bar.

is necessary to connect together all the positive sides as well as all the negative sides of the compound windings, as indicated in fig. 1. Any cables or bus-bars used for this purpose are known as *equalising cables or bars.* The necessity for these connections is seen from the following. The compound winding of a generator raises the pressure in proportion to the current flowing through it, and if, in a system of parallel-operated compound generators without the equalising connection, the current given by one machine were slightly greater than the currents from the others, the pressure of that machine would increase. With this increase in pressure above the other machines, a still greater current would flow, and so raise the pressure further. The effect is therefore cumulative, and in time the one generator would be carrying too great a proportion of the whole current of the system.

With the equalising connection, whatever the current flowing from each machine, the currents in the various compound windings are all equal, and so the added pressure due to the compound winding is practically the same in each machine. Any inequality in output from the machines is readily eliminated by adjusting the shunt currents by means of the shunt rheostats.

In fig. 2, A, B, C represent compound-wound continuous-current generators. Se represent the series windings, Sh the shunt windings. It is obvious that the pressures *a*, *b*, *c*

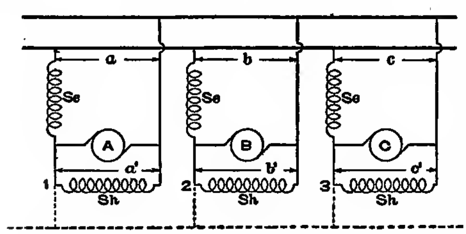


Fig. 2.—Diagram to Explain Equalising Bars or Cables

must be the same, since each machine is connected to the same bus-bars, but it does not follow that the pressures *a'*, *b'*, *c'* are the same. If, however, the terminals 1, 2, 3 be connected together by means of an equalising bar, as shown dotted in the above figure, it is obvious that the armature terminal pressure of each machine, *i.e.* *a'*, *b'*, *c'*, must be the same. The *equalising current* is the interchange of current which takes place through the equalising bar between the machines to bring this about.

When compound-wound machines are run in parallel in this way, there can be no reversal of current in the compound winding of any one of the generators. This constitutes a further advantage of equalising-bar connections.

Equalising Connection. See CONNECTIONS, EQUIPOTENTIAL.

Equalising Current. See EQUALISING BARS OR CABLES; CONNECTIONS, EQUIPOTENTIAL.

Equalising Feeder, an interconnecting feeder. See FEEDER.

Equalising Rings. See CONNECTIONS, EQUIPOTENTIAL.

Equifrequent Vibrations. See COIL, INDUCTION.

Equipment, outfit; especially the complete outfit of motors, controllers, switches, wiring, rheostats, &c., required to equip a car or locomotive for electric traction. *Single-phase* and *three-phase equipments* may require transformers in addition to the foregoing apparatus.

Equipotential. See POTENTIAL, ELECTRIC.

Equipotential Connections. See CONNECTIONS, EQUIPOTENTIAL.

Equipotential Surface, Electrostatic, a surface which may be either an inter-face between a conductor and non-conductor, or merely a geometrical surface in one medium, along which the potential is constant, *i.e.* along which there is no electric force. Where gravitation is the force an equipotential surface is called *level.* On the earth equipotential surfaces are approximately spheres surrounding the centre. The electric equipotential surfaces surrounding a sphere are also spheres. [J. E-M.]

Equipotential Surface, Magnetic, a surface in a magnetic field along which a free magnetic pole would *not* tend to move. Such a surface is therefore exactly at right angles to the lines of force at every point in the surface. [D. K. M.]

Equivalent Air Gap. See GAP RELUCTANCE.

Equivalent Conductor. See CONDUCTOR, EQUIVALENT.

Equivalent Reactance. See REACTANCE, EQUIVALENT.

Equivalent Resistance. See RESISTANCE, EQUIVALENT.

Equivalent Sine Wave. See SINE WAVE.

Erection of Line. See LINE ERECTION.

Erg, the energy expended when a force of 1 dyne (which see) is overcome through a distance of 1 cm. The erg is equal to 0·0000001 joule (or watt-second). The kelvin (kw hr) is equal to $3{\cdot}6 \times 10^{13}$ ergs. See ENERGY.

E.S.C. Standards of Resistance, the Engineering Standards Committee (1906) Standards of Resistance for commercial copper. See RESISTANCE, MATTHIESSEN'S STANDARD OF.

Ethyl Alcohol. See ALCOHOLS.

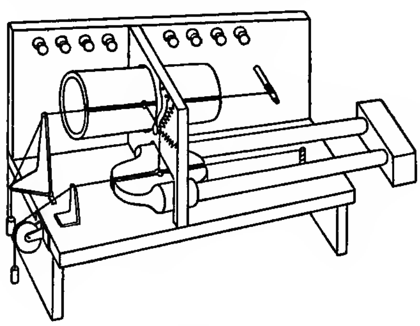
Eureka Wire, the trade name of a well-known resistance wire made of an alloy of copper and nickel. Its specific resistance is about 50 microhms per cm cube, and its increase of resistance per degree Centigrade of increase of temperature is stated to be 0·00000018 of its resistance at 0° C., and is thus negligible for all practical purposes. Its composition is almost identical with that of constantan (which see). It does not appreciably deteriorate when run at high temperatures. See HIGH-RESISTANCE ALLOYS; WIRE, RESISTANCE.

Evaporation, Temperature of. See STEAM.

Evaporative Condenser. See CONDENSER, STEAM.

Evolute Connections. See CONNECTIONS, BUTTERFLY.

Ewing Curve-tracer, an apparatus for drawing directly the hysteresis or B-H curve



Ewing Curve-tracer

of a specimen of iron. The mirror shown in the fig. is so arranged that it is capable of deflection, either vertically or horizontally. The vertical motion is produced by means of the displacement of a wire carrying a constant current lying in the gap of an electromagnet whose limbs constitute the specimen. The horizontal motion is due to the pull of a wire carrying the magnetising current and lying in the gap of an electromagnet of constant strength. If a beam of light be thrown on to a screen from the mirror, it will, by its motion, plot out the magnetisation curve of the specimen. See DRYSDALE METHOD OF TESTING IRON AND STEEL; PERMEAMETER; 'Bridges for Magnetic Measurements' under BRIDGES; HOPKINSON METHOD OF IRON TESTING; RING METHOD OF MAGNETIC TESTING.

Ewing Hysteresis Tester, an instrument designed by Ewing for determining, by a single direct observation, the hysteresis loss of a sample of iron. The sample consists of a bundle of iron strips $\frac{5}{8}$ in wide and 3 in long. These are clamped to a carrier of non-magnetic material which can be rapidly revolved between the poles of a C-shaped permanent magnet mounted on knife edges in such a way as to be free to swing about the axis of rotation of the specimen. In consequence of the hysteresis in the specimen, the magnet is deflected from its zero position, and the amount of this deflection is indicated on the scale of the instrument by a pointer attached to the magnet. Each instrument is provided with two standardised samples, for which the hysteresis is given, and the process of making a measurement consists simply in comparing the deflections produced by these samples with that produced by the specimen under test. (See Ewing's Paper in the Journ. I.E.E. for April 25, 1895.) See HYSTERESIS; STEP-BY-STEP METHODS OF MAGNETIC TESTING.

Ewing Permeability Bridge. See 'Bridges for Magnetic Measurements' under BRIDGES.

Ewing's Theory of Magnetism. See MAGNETISM, EWING'S THEORY OF.

Excello Arc Lamp. See LAMP, ARC.

Excess-voltage Preventer.—In various systems in which electrical machinery is employed, and notably in systems of regenerative control of tramway motors, conditions are liable to arise where, unless provision is made by means of an auxiliary device termed an *excess voltage preventer*, the electrical pressure would rise to a value sufficiently in excess of the normal pressure to occasion damage to apparatus in the circuit.

Excitation, the provision of the necessary current to produce a magnetic field in any magnetic circuit. In many dynamo-electric machines a separate winding is provided, the sole purpose of which is to supply the necessary magnetisation. This winding forms a circuit which is known as the *exciting circuit* or *exciting winding.* The current flowing through this circuit is the *exciting current*, and the emf at the terminals of the circuit is the *exciting voltage* or *exciting emf.* In some kinds of apparatus, such as static transformers and some ac motors, there is no separate winding the sole function of which is to provide the excitation. In this case, though there is no exciting circuit, that component of the current which provides the magnetising force is still known as the *exciting current.*

A generator of continuous electricity may be excited from an independent source of supply. It is then said to be *separately excited* (see fig. 1). The exciting current may

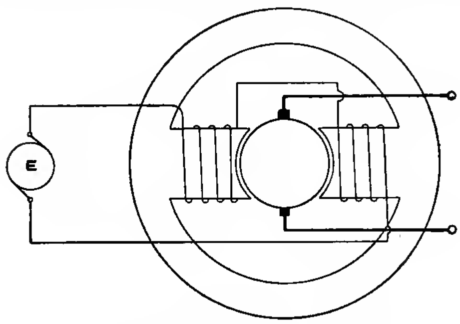


Fig. 1.—Separate Excitation. E, Exciter.

be taken from the generator itself, when it is said to be *self-excited.* The same terms are frequently applied (with less accuracy) to cc motors—a motor is said to be separately excited if the magnetising current is derived from a different source of supply from that furnishing the main current; it is said to be self-excited if the magnetising and main currents are both obtained from the same source.

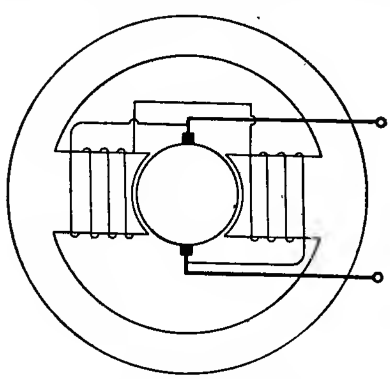


Fig. 2.—Shunt Excitation

The excitation of a self-excited cc generator or motor may be *shunt excitation* (see fig. 2) when the exciting circuit is connected in parallel with the armature circuit, or *series excitation* (see fig. 3) when the exciting circuit is connected in series with the armature circuit, or it may be partly shunt and partly series, which is called *compound excitation* (see fig. 4).

With shunt excitation, the excitation being independent of the load, the pressure will be approximately constant; the armature reaction will, however, cause the terminal pressure to drop to a certain extent as the load increases.

With series excitation the excitation varies

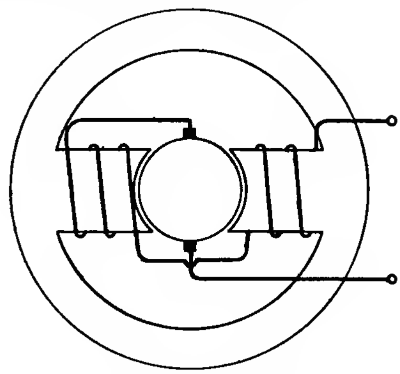


Fig. 3.—Series Excitation

directly as the load. Consequently the terminal pressure will increase to a maximum at full-load and fall to a minimum at no-load.

Compound excitation, consisting of some turns of shunt winding and some of series winding, is used to compensate for the drop of pressure which would otherwise occur at the terminals of the machine as the load

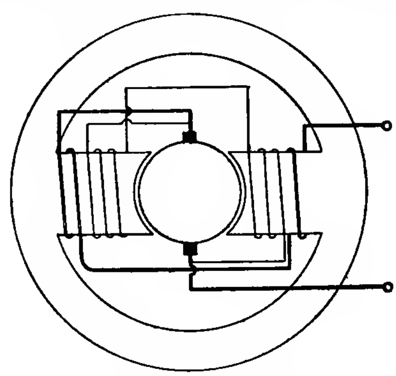


Fig. 4.—Compound Excitation

increases. The amount of regulation thus obtained is called the *compounding* of the machine. If sufficient series turns are put on to cause the terminal pressure to *increase* with increase of load, the machine is said to be *over-compounded.* If the series turns are so few that the terminal pressure still falls as the load increases, it is said to be *under-compounded*; *e.g.* generators for traction work are frequently *over-compounded,* so that the increased terminal pressure may compensate for the increased drop on the line at high loads. When the series turns are so proportioned as to give the same terminal pressure at all loads, the compounding is sometimes termed *flat compounding*, from the fact that the curve connecting terminal pressure with main current then becomes a horizontal straight line. Ac generators are usually separately excited, but several methods have been devised for supplying the whole or part of the excitation from the generator itself, the object being to compound the generator so as to make the terminal pressure independent of the load. See COMPOUNDING, AUTOMATIC; AUTOMATIC REGULATION OF VOLTAGE; ALTERNATOR, COMPOUND-WOUND; GENERATOR.

[W. B. H.]

Excitation, Full, the maximum excitation for which the magnet winding is designed. In many cases the excitation of a dynamo is weakened, for the purpose of regulating the pressure, by means of the introduction of a regulating resistance; when all this resistance is cut out, full excitation is obtained.

Excitation Curve. See CURVE, CHARACTERISTIC.

Excitation Regulation. See REGULATION; ALTERNATOR, PRESSURE REGULATION OF AN.

Exciter.—

['*Exciter.*—A dynamo used for exciting the field magnets of another machine.'—I.E.C.]

Exciting Circuit. See EXCITATION.

Exciting Current. See EXCITATION.

Exciting emf. See EXCITATION.

Exciting Frequency, the frequency or periodicity of the current supplying the main magnetic field in an ac motor.

Exciting Voltage. See EXCITATION.

Exciting Winding. See WINDING; EXCITATION.

Exhausted Accumulator Cell. See ACCUMULATOR, EXHAUSTED CELL OF.

Exhaust Pressure. See PRESSURE, EXHAUST.

Exide Accumulator. See ACCUMULATOR.

Exosmose, Electric.—An electric gradient of potential may assist a liquid to flow through a more or less porous membrane. The phenomenon is known as *electric exosmose.*

Expanded-terminal Bond. See BOND.

Expanding Mandrel. See 'Earthenware Ducts' under CONDUIT, UNDERGROUND.

Exploring Coil. See COIL, EXPLORING; COIL, EARTH; GRASSÔT FLUXMETER.

Explosion, Situations in which there is danger of. See SITUATIONS IN WHICH THERE IS DANGER OF EXPLOSION.

Exposed Work. See BURIED WORK.

Expulsion Fuse. See FUSE.

External-armature Generator. See 'Revolving Field Type of Alternator' under ALTERNATOR.

External Circuit. See CIRCUIT, ELECTRIC.

External Insulating Bush. See BUSH, INSULATING.

External Latent Heat. See STEAM.

External Lightning Phenomena. See STATIC DISTURBANCES.

External Load. See LOAD, EXTERNAL.

External Rotating Field. See FIELD, ROTATING.

Extra Current. See CURRENT INDUCTION.

Extra High Pressure. See PRESSURE.

Extra High-pressure Current. See CURRENT, HIGH-PRESSURE.

F

Factor of Safety.—

['*Factor of Safety.*—The ratio of the *ultimate breaking strength* to the *maximum normal working stress.*'—I.E.C.]

Falk Cast-welded Rail Joint. See WELDED RAIL JOINT.

Fall of Potential.—This term relates to the electrical pressure required to force a given current through or along a conductor. As a numerical illustration, we may take the case of a dynamo supplying a batch of lamps at the far end of a pair of conductors. The current required is, say, 100 amp, and the pressure at the lamps is 100 volts. Taking the resistance of the conductors at 0·025 ohm, the fall of potential along the conductors will be (100 amp × 0·025 ohm =) 2·5 volts, so that the pressure at the terminals of the dynamo must be 102·5 volts. The fall of potential is usually referred to as the *drop* *in the conductor.* As the current traverses the armature, the series-field coils, and the brushes, there is a still further fall of potential, and this is known as the *internal drop.* Taking the resistance of armature, series-field coils, and the brushes as aggregating 0·035 ohm, the fall in these portions of the circuits will be 3·5 volts, so that the internal emf generated in the armature must be $(100 + 2{\cdot}5 + 3{\cdot}5 =)$ 106 volts.

Thus, in order to obtain 100 useful volts at the point of application we must generate 106 volts in the dynamo, so that in this particular case the pressure lost amounts to 6 volts. In the above illustration continuous electricity is assumed, and it will be noted that the loss is proportional to the resistance of the conductors, and is therefore known as the *ohmic loss* or *ohmic drop.*

In the case of conductors conveying alternating electricity, there is, in addition to the ohmic drop, a further drop due to inductance, and known as the *inductive drop.*

When large solid conductors carry alternating electricity of high periodicity, the inductance disturbs the distribution of the current in the cross section of the conductor, causing the greater part to flow in the outer portion of the conductor, practically none flowing in the central portion. This phenomenon is known as the *skin effect.* This virtually decreases the cross-sectional area of the conductor, thus increasing its resistance and augmenting the ohmic loss. With the low frequencies now used, this further loss is usually negligible, except in conductors of large cross section, or in iron or steel conductors, or in wireless telegraphy or telephony, where very high frequencies are employed. In the rail-returns employed with sp railways the skin effect is very pronounced, even at the low periodicities usually employed in sp traction. [C. W. H.]

Fan-shaped Aerial Transmitter. See 'Aerial Transmitter' under TRANSMITTER.

Farad, the unit of electric capacity in the practical or Q.E.S. system of units (which see), being the capacity of a condenser such that 1 coulomb of electricity will raise it to the potential of 1 volt. The farad is much larger than the capacities usually met with in practice. The mfd, or the millionth part of a farad, is accordingly employed in practical work as the unit of capacity.

If the capacity of a condenser is given in farads, the periodicity of the supply in cycles per sec, and the pressure at the terminals of the condenser in volts, then the current, in amperes, flowing through the condenser (sometimes termed the *capacity current* and sometimes the *charging current*) is equal to $2 \times \pi \times$ periodicity $\times$ pressure $\times$ capacity.

['*Farad.*—The practical unit of electrical capacity. It is inconveniently large, and, therefore, capacities are usually reckoned in mfd.'—I.E.C.]

See CAPACITY, ELECTROMAGNETIC; CAPACITY, ELECTROSTATIC; CAPACITY REACTANCE; CAPACITY CURRENT; CURRENT, CONDENSER; CURRENT, LEADING.

Faraday Effect, a term usually applied to Faraday's discovery that the plane of polarisation of light is affected by transmission along a piece of heavy glass in a strong magnetic field in the direction of the lines of force.

Faraday's Cube, a large box or small room made of tinfoil (*i.e.* of conducting material), and placed on insulating legs. Faraday electrified such a cube by means of an electrostatic machine while he conducted experiments inside it. He found that the electrification was entirely on the outside, and did not in any appreciable way affect the conditions in the interior.

Faraday's Dark Space.—Faraday discovered that there is always a dark space in a vacuum-tube discharge between the positive and negative glows, which varies in position with the degree of exhaustion of the tube.

Faraday's Disk.—Faraday showed that if a magnetised bar be suspended above a revolving copper disk, it tends to follow the motion of the disk. The action is due to the currents induced in the copper disk by its motion through the field of the magnet. See also ARAGO'S DISK; ARAGO'S ROTATIONS.

Faraday's Law of Electromagnetic Induction. See INDUCTION, ELECTROMAGNETIC.

Faradic Brush, an obsolete term applied to BRUSH DISCHARGE (which see).

Fault.—The term *fault* is somewhat comprehensive, and may be applied either to a defect in insulation which allows a leakage of current to take place, or to a defect in the continuity of a conductor which causes a restriction of the flow of current.

CONTACT FAULT.—A contact fault is of the latter description, and may be caused by slackness of screws in terminals or switchgear, allowing current-carrying pieces to lie loosely upon one another instead of pressing them firmly up into good contact.

['*Fault*, any local defect in the insulation or continuity of a conductor which interferes with its use.' —I.E.C.]

Faure Accumulator. See 'Lead Accumulators' under ACCUMULATOR.

Fe, the chemical symbol for *iron* (which see).

Fechner's Constant. See LAW, FECHNER'S.

Fechner's Law. See LAW, FECHNER'S.

Fed-in Winding. See WINDING, FED-IN; HAND WINDING.

Feeder Box or Pillar.—

['*Feeder Box or Pillar* for tramways or railways: A box or pillar containing switches, links, and sometimes fuses for connecting sections of trolley wire or conductor rail with feeders. For electric lighting and power: A box containing links and sometimes fuses for connecting feeders with distributing networks.' —I.E.C.]

Feeder Cable. See FEEDERS.

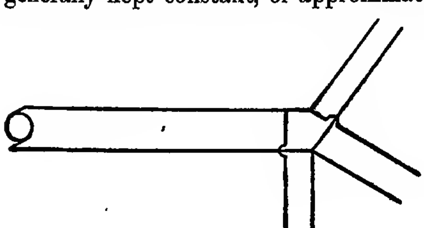
Feeder Panel. See PANEL, FEEDER.

Feeder Pillar. See FEEDER BOX OR PILLAR.

Feeders.—

['*Feeders*, conductors for conveying electrical energy from the place where generated or transformed to feeding points or substations. Not used for supplying consumers directly, owing to the varying pressure along their length.'—I.E.C.]

The pressure at the centre of distribution is generally kept constant, or approximately



Feeder

constant, by altering the pressure applied to the generating-station end of the feeder, so as to compensate for the pressure-drop in the feeder, which may be considerable. The size of a feeder cable is frequently determined by assuming various areas of conductor, working out the corresponding money values of the energy lost in the cable per annum, and of the interest, depreciation, and maintenance for the same period, and taking that area which gives the lowest total expenditure. Sometimes the resulting size of cable has to be modified to suit the pressure-regulation that is possible at the generating end, the permissible maximum current density in the type and size of cable chosen, the desirability of allowance for a future increased demand in the distribution area, and the necessity for keeping down capital expenditure, even at an increased total annual cost. The figure represents diagrammatically a feeder connecting a source of electricity with a centre of distribution. See also CENTRE OF DISTRIBUTION.

NEUTRAL FEEDER, a feeder cable connected to the neutral terminal of the system.

POSITIVE FEEDER, a feeder cable connected to the positive side of the system.

NEGATIVE FEEDER, a feeder cable connected to the negative side of the system. Negative feeders are of particular interest on tramway circuits in this country, owing to the fact that the Board of Trade limits the drop in pressure in the rail return to 7 volts, and that negative feeders have therefore to be laid to suitable points to relieve the rails of part of the return current. Boosters are frequently inserted in negative feeders to compensate for the drop in pressure over their length.

INTERCONNECTING OR EQUALISING FEEDER, a conductor connecting two distribution centres, and so helping to equalise the loads on the feeders, and offering an alternative route to either centre in the event of a breakdown in the feeder. (Ref. 'Central Station Electricity Supply', Gay and Yeaman; 'Electrical Transmission of Energy', A. V. Abbott; 'Electric Traction', Rider.)

Feeder Switch. See SWITCH, FEEDER.

Feeding (in Arc Lamps). See 'Regulating Mechanism' under LAMP, ARC.

Feeding Point.—

['*Feeding Point*, the point or junction of a feeder with the network.'—I.E.C.]

Feet of a Frame, the side projections cast on a frame, which form a means of supporting it upon the bedplate or foundation plate. On large machines a third foot is often provided at the centre of the bottom of the frame, in order to take up the sag of the bottom half of the frame, and also to minimise that on the top half. See FRAME, STATOR; FOUNDATION PLATE.

Ferranti Continuous-current Meter. See METER, FERRANTI.

Ferranti Effect, the term usually applied to a rise of pressure at the terminals of an alternator or of an alternating transformer, when unloaded or lightly-loaded cables are connected thereto.

One effect of switching an inductive circuit, or the equivalent, on to an alternator having large armature reaction and inductance, is to produce a more or less considerable drop of pressure at the terminals of the machine. In this case the current supplied lags behind the terminal emf. When cables, or the equivalent, are switched on, in place of the inductive load, the current *leads* relatively to the terminal emf, and the effect of this leading current, in combination with the inherent reaction and inductance of the alternator, tends to produce the opposite effect, viz. to raise the terminal emf.

Similar effects are observed when circuits containing capacity are connected to transformers having large magnetic leakage, producing an apparent variation in the ratio of transformation.

Attention was first prominently directed to this phenomenon in 1890, when considerable rises of pressure were observed at the terminals of the alternators and transformers at the Deptford Supply Station when the 10,000-volt Ferranti concentric trunk mains between Deptford and London were switched on. [M. B. F.]

Ferranti Rectifier. See RECTIFIER.

Ferraris Ammeter. See AMMETER.

Ferraris-Arno Phase Transformer. See TRANSFORMER, PHASE.

Ferraris Wattmeter. See WATTMETER.

Ferric, of iron. Such terms as *ferric magnetic circuit* and *ferric inductance coil* are now rarely employed.

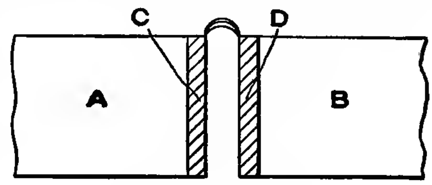
Ferro-alloys, a class of iron in which varying percentages of special materials are added. Iron possesses to a most remarkable degree, the quality of changing its properties when small quantities of foreign matters are added. Carbon, especially, almost completely dominates the behaviour of the iron into which it enters. *Ferro-tungsten* contains a small percentage of tungsten, which renders the alloy hard and tenacious. *Ferro-manganese* contains up to 5 per cent of manganese. Ferro-manganese alloys are generally characterised by extreme hardness, low magnetic permeability, and high electrical resistance. Ferro-manganese is remarkable as being, in certain cases, almost non-magnetic. *Ferro-silicon* is hard and brittle, but to a less degree if a small quantity of manganese be also present. This alloy exhibits a decreased hysteresis loss under alternating magnetic induction. Further information on ferro-alloys will be found under the heading STEEL. See also HIGH-RESISTANCE ALLOYS; WIRE, RESISTANCE. [J. S. S. C.]

Ferro-magnetic, applied to a substance whose permeability is substantially greater than unity, as iron, nickel, cobalt.

Féry Pyrometer. See PYROMETER, ELECTRIC.

Fessenden System of Wireless Telegraphy. See WIRELESS TELEGRAPHY.

Fessenden's Experiment. — The two plates A and B of the accompanying fig. are



Fessenden's Experiment

10 mm apart, and are maintained at a difference of potential of 10,000 volts by suitable connections with a source of ac. This pressure will not suffice to set up an arc between A and B. But the insertion of the glass plates C and D, which are each 2·5 mm thick, and which have a specific inductive capacity eight times greater than air, is followed by a discharge across the glass and the remaining 5 mm thickness of air. The subject is discussed at p. 140 of vol. xv (1898) of the Trans.A.I.E.E.; and also at p. 25 of Turner and Hobart's 'Insulation of Electric Machines'. See CABLE, GRADED; GRADING OF INSULATION.

Fibre or Vulcanised Fibre, an extremely hard, tough solid. It is manufactured by a secret process from vegetable fibre, and is made in three colours, black, red, and a greyish-white. For this reason it is sometimes sold under the names *black, red, white* fibre. Of the three, the *red* and *white* vulcanised fibres are most commonly used, and in all their properties these two grades closely resemble each other. The specific gravity is about 1·3 to 1·4, and the material is manufactured in sheets measuring about 1·8 m by 1·0 m, and in any thickness from 0·4 mm to 32 mm. It is also possible to make tubes and rods from the raw material, but at no stage in its manufacture can it be moulded. Fibre has great strength, and can be sawn, drilled, punched, or threaded. It has a certain amount of elasticity, is very durable, and will take a good polish. It rapidly absorbs either hot or cold water, and swells on so doing, but can be dried without injury. Its insulating properties are somewhat uncertain, being affected by the amount of moisture it contains.

BLACK FIBRE.—The black vulcanised fibre contains a higher percentage of moisture than either the red or white vulcanised fibres. It is not non-inflammable, but has come into very extended use for purposes where its excellent mechanical properties render it suitable.

INDURATED FIBRE, the trade name of a material closely resembling vulcanised fibre, which is claimed to be more flexible and not to absorb moisture so rapidly. (Ref. 'The Insulation of Electric Machines', Turner and Hobart.) [H. D. S.]

Field.—The term field is employed in various connections in electrical engineering. Usually it denotes the part of a dynamo-electric machine which carries magnetising windings, and from which the magnetic flux emerges on its way to the armature, the two chief parts of the dynamo-electric machine thus being the field and the armature. The term *field* is, however, also employed in connection with other electromagnetic apparatus, and also in connection with electrostatic and electromagnetic fields in general. See FIELD-MAGNET; FIELD OF FORCE; FIELD, ELECTROSTATIC; FIELD, MAGNETIC.

Field, Alternating, a magnetic field periodically varying in intensity and direction. The term is usually confined to a magnetic field the variation of which more or less approximately follows a sine law. A field which varies periodically in intensity without changing its direction is known as a *pulsating field.*

Field, Bipolar, a field having but one pair of poles. Most of the earlier continuous-electricity dynamo-electric machines employed bipolar fields. See BIPOLAR TYPE; GENERATOR.

Field, Bore of. See BORE OF FIELD.

Field, Commutating, (1) that magnetic field in which the armature coil, short-circuited by the brushes, is situated at the moment of reversal. (2) The field due to a commutating pole. See INTERPOLES.

Field, Compensating. See COMPENSATING FIELD; COMPENSATING WINDING; COIL, COMPENSATING; COMPENSATION.

Field, Drag of, (1) the tangential component of the magnetic pull opposing rotation in a generator and in the direction of rotation in a motor. (2) The component of the magnetic pull tending to move an armature or rotor endwise if it is not symmetrically placed in the field. See END THRUST; END PLAY.

Field, Electric. See ELECTRIC FIELD.

Field, Electromagnetic. See FIELD, MAGNETIC.

Field, Electrostatic.—

['*Field, Electrostatic,* any region in which there are electric lines of force, as in the space between a positively-charged surface and a negatively-charged surface.'—I.E.C.]

See LINE OF INDUCTION.

Field, Magnetic, the space in the neighbourhood of a magnet or other source of mmf; a space subject to magnetic stress.

(1) Such a field exerts a directive force on a magnet. (2) If a straight conductor is moved across it an emf is induced between the ends of the conductor. (3) The plane of polarisation is rotated if a beam of polarised light is sent along the direction of the field. See LINE OF INDUCTION.

['*Field, Magnetic,* any region in which there are magnetic lines of force, as in the space between the poles of a magnet or within a magnetising coil. The intensity of the field is usually expressed in cgs measure as the number of lines per sq cm. 1 line per sq cm is called a *gauss* (which see).—I.E.C.]

THE FIELD DENSITY is the number of lines of magnetic force per unit area, usually per sq cm, and is generally denoted by the symbol B. The total number of lines, considered as a whole, is spoken of as the *magnetic flux* or *field flux.*

MAGNETIC FIELD STRENGTH.—This is measured by the force exerted by the field upon a magnetic pole of unit strength. It may also be measured in terms of the force upon unit length of a conductor carrying unit current.

UNIFORM MAGNETIC FIELD, a space in which the effects of a magnetic field are exhibited in a uniform degree throughout. See also ROTARY MAGNETIC FIELD; FIELD, ROTATING. [D. K. M.]

ELECTROMAGNETIC FIELD, a term sometimes employed to indicate that the field is occasioned by an electromagnet as distinguished from the field of a permanent magnet.

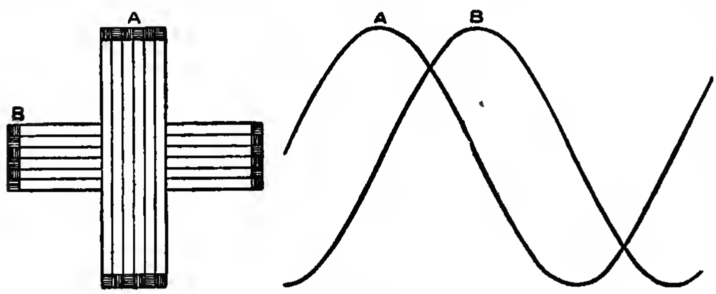
Field, Multipolar, a field having more than one pair of poles. With the exception of turbo-alternators, which are sometimes bipolar, almost all alternating generators and motors are multipolar, as are also almost all modern dynamos and motors for continuous electricity.

Field, Pulsating. See FIELD, ALTERNATING.

Field, Quadripolar, a field-magnet having four poles, alternately north and south. Four poles are more frequently employed than any other number of poles in the construction of modern continuous-electricity motors of small and medium size.

Field, Reversing. See REVERSING FIELD.

Field, Rotating, the resultant magnetic field produced by a system of coils symmetrically placed and supplied with polyphase currents. Consider the simplest case of two coils placed with their planes at right angles, as shown in section in the fig. Let A and B be the two coils supplied with two-phase currents as represented by the sine curves A and B. Now when A carries zero current, B carries maximum current, and the direction of the magnetic field is along the axis of B. One quarter of a period later, A carries maximum and B zero current, and the field-direction is now along the axis of A, *i.e.* it has turned through one-quarter of a revolution. The resultant field has a constant strength, and its speed of rotation in rps is, for a bipolar structure, of which the figure is diagrammatic, equal to the frequency in cycles per sec. The two coils shown above may be replaced by three coils fed with three-phase currents, or n coils fed with n-phase currents.



Rotating Field

A UNIFORM ROTATING FIELD is one whose vector rotates at a uniform angular velocity, and has a constant value. The effect of harmonics in the emf wave applied to the coils is to superimpose upon the main field subsidiary fields which rotate at frequencies corresponding to those of the harmonics. The principle of the rotating field finds its chief practical application in the induction motor.

ELLIPTIC ROTATING FIELD, a magnetic field of which the direction in space and the magnitude vary with time in such a way that the field is capable of analysis into two constituent magnetic fields, which, while varying according to a sine law, are in quadrature with one another, have their axes displaced 90° in space, and have unequal maximum values; a magnetic field characterised in that when reduced to a bipolar system, the curve which represents in polar co-ordinates the connection between direction in space and intensity is an ellipse.

IRREGULAR ROTATING FIELD, a magnetic field of which the direction in space varies, and characterised in that while the successive directions are defined by a continuously increasing angle, either the rate of angular change of direction is not constant, or the intensity of the field is not constant. See ROTARY MAGNETIC FIELD.

EXTERNAL ROTATING FIELD, (1) a field-magnet designed to rotate round the outside periphery of a stationary armature. (See 'Overhung Type' and 'Umbrella Type' under ALTERNATOR.) (2) The rotating magnetic field produced by the polyphase windings on the stator of an induction motor when that stator is the external member of the motor.

Field, Stiff, an expression used in connection with the magnetism of dynamos, and indicating a field so proportioned that the armature current cannot, owing to the configuration of the magnetic circuit in the neighbourhood of the gap, cause great fluctuations in the strength or the direction of the flux. This end is attained by various means which create a high reluctance across the pole face, such as running the magnetic density up to a high value, or by making radial slots in the pole face. The use of high tooth density is the most effective means of providing a stiff field. See FIELD, STRONGLY SATURATED.

Field, Strongly Saturated.—When the field-magnets of a dynamo are worked at such high magnetic inductions as to be well over the bend of the magnetisation curve (see Magnetisation, Curve of), they are said to be strongly saturated. Strongly saturated fields are useful in minimising the effects of armature interference, and thus conduce to good commutation, and also to stability of the generator. See Stability of Electric Generator; Field, Stiff.

Field, Uniform, one of uniform intensity; having the same number of lines per sq cm through any cross section at right angles to the direction of the field. Applicable to both magnetic and electrostatic fields.

Field Coil. See Coil, Field; Coil, Magnet.

Field Density. See Field, Magnetic.

Field Excitation, the winding on the magnets of a dynamo or motor; numerically, the number of ats on the magnets of the dynamo or motor. See Excitation.

Field Flux. See Field, Magnetic.

Field-magnet.—

['*Field-magnet,* any magnet or electromagnet employed for the purpose of providing a magnetic field. (It is incorrect to speak of the field-magnets of a dynamo or motor as its *fields*; they should be called its *magnets* if the term *field-magnets* is too long.')—I.E.C.]

Field-magnet Winding. See Winding, Field-magnet.

Field of Force, a space subject to magnetic or electrostatic stress; the former arising through the neighbourhood of a magnet or of a current which can exert mmf, and the latter through neighbouring charges or pd.

Field of Force of a Current.—This consists of lines embracing the conductor which carries the current, each line being in a plane at right angles to the current. The intensity of the field due to a straight conductor is inversely proportional to the distance from the wire, and is equal to $\frac{2i}{10r}$, where r is the distance from the wire and i the current in amp. (Ref. Hobart's 'Electricity', p. 61.)

Electromagnetic Field of Force, a magnetic field of force occasioned and maintained by an electric current. See also Field, Magnetic.

Electrostatic Field of Force, any region in which there is steady electric force. See also Field, Electrostatic.

Field-regulating Rheostat. See Regulation; Regulator, Potential.

Field Regulator, Carbon. See 'Carbon Regulator' under Regulator, Potential.

Field Spool. See Spool, Field or Magnet; Coil, Field; Coil, Magnet.

Field Strength. See Field, Magnetic.

Field Turns, the number of turns on the magnets of a dynamo-electric machine, or of some other electromagnetic apparatus.

Field Winding, Concentrated. See Winding, Concentrated Field.

Figure-8 Wire, a trolley wire for use as overhead conductor in traction equipment, which is drawn to the shape indicated in the fig. (resembling a figure 8), and generally of a cross section equal to 4/0 or 5/0 Standard Wire Gauge. The wire is gripped by the adjustable clamps of a mechanical ear (see Ear), permitting of simpler methods of suspension than with round sections, but being more difficult to handle during installation.

'Figure-8' Wire

Figure of Loss, the total iron loss, in w per kg, in a laminated core, for B = ±10000, and a periodicity of 50 cycles per sec. See Specific Hysteresis Loss; Tester, Epstein Hysteresis; Hysteresis; Ewing Hysteresis Tester; Step-by-step Methods of Magnetic Testing; Blondel Hysteresimeter.

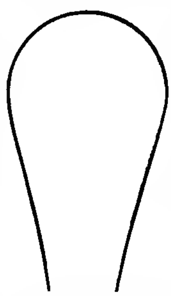
Figure of Merit.—

['*Figure of Merit* (*a*) of a galvanometer. The deflection in mm per micro-amp at a scale distance of 1 m. (*b*) The current in amp required to produce a deflection of 1 mm at a scale distance of 1 m. Sometimes expressed as the number of megohms through which 1 volt will give that deflection. The complete period of a swing is taken at 20 sec unless otherwise stated. (*c*) Of a telegraph instrument. The minimum current necessary to work the instrument with absolute certainty.'—I.E.C.]

Filament, a term widely applied to the conductor contained within the bulb of an electric incandescent lamp. It has recently (Journ.I.E.E., vol. 41, p. 368) in connection with metallic-filament lamps been urged by Mordey that it would be better to employ the word *wire* instead of filament. Mordey points out that the word *filament* in connection with lamps is a term introduced by the patent agents and lawyers over a patent case. It was imported from the physiologists and botanists, and he expresses the opinion that it is far better 'to simplify its name, and call it what it is, a *wire lamp*, using a simple one-syllable Anglo-Saxon word'.

Graphitised or Metallised Filament.—By a special intense-heating process the carbon of which the crude filament in the incandescent electric lamp is composed may be partially converted into a *graphitic* or *metallic* state, when it is found to possess a positive temperature coefficient. Filaments so prepared are said to stand greater temperature than those of the ordinary variety, and from the characteristic noted above, are termed *metallised* or *graphitised*. (Ref. 'A New Carbon Filament', Trans. A. I. E. E., vol. xxiv, p. 838, 1905, Howell.)

Horseshoe Filament.—The earlier filaments in electric lamps intended for 1 pr were made in the form of a horseshoe, as shown in the fig. Now that the use of higher pressures coupled with low cp lamps has become customary, it is usually found necessary to depart from the horseshoe form and introduce several loops into the filament in order to secure the requisite resistance. This has the further advantage that a better distribution of light is secured.



Horseshoe Filament

Drawn Filament, a filament produced by drawing a metal having suitable physical properties into a very fine wire. One example of this type is furnished by the tantalum lamp, the filament of which is composed of finely drawn tantalum wire.

Squirted Filament, a filament constructed by reducing the material of which it is composed to a finely divided or plastic condition, and subsequently squirting it through a very fine orifice.

Pasted Filament.—A filament composed of the rare metals may be constructed by reducing the metals to an impalpable powder, and mixing this powder with some binding material, thus forming a paste. This paste is subsequently squirted through a fine orifice in the ordinary way. Filaments so prepared are termed *pasted filaments*.

Disintegration of Filaments.—During the life of an incandescent electric glow lamp particles of carbon are projected from the filament, and are deposited in a light-obstructing film on the inner surface of the bulb of the lamp. This process is termed *disintegration*, and is believed to be partially due to the forcible expulsion of gases previously absorbed by the filament. Lamps in which this disintegration of the filament has occurred present a more or less blackened appearance, and are said to have *blackened*. The expression *blackening of incandescent lamps* applies to this occurrence.

Deformation of Filament.—During the life of an electric glow lamp the filament may become weakened at some point, or, by lacking sufficient support as a whole, it may become altered from its original shape, or *deformed*. This is liable to occur in the case of the earlier forms of metallic-filament (or *wire*) lamps, if they are not burnt in a vertical position. More recently, however, the introduction of better methods of supporting (or 'anchoring') the filament has to a great extent removed this difficulty.

Deformation is also liable to occur in photometrical testing when the glow lamp is spun rapidly about a vertical axis in order to determine its mean horizontal cp.

Ageing of Filaments.—The alteration in cp which commonly occurs in the first 50 hours or so of the life of a glow lamp, would be inconvenient in the case of a lamp intended to serve as a standard. For this reason it is customary to artificially *age* lamps intended for this purpose, by running them on their normal pressure for about 50 to 100 hours before final calibration and use as a standard.

Flashing of Filaments.—The durability of the carbon of which the crude filament is composed can be improved by the process of *flashing*. In this process the filament is enclosed in an atmosphere of gaseous hydrocarbons, and is brought to incandescence by the passage of an electric current.

As a result, a layer of carbon in a graphitic form is deposited on the surface of the filament, which is thus rendered more homogeneous and non-porous, while the gases absorbed by the carbon are, to a great extent, driven out, and the subsequent deterioration of the filament, due to the gradual expulsion of these gases, is largely prevented.

Filaments so prepared are termed *treated* or *flashed filaments*. [L. G.]

['*Flashing*.—(*a*) Any process of manufacture involving the temporary electrical superheating of a glow-lamp filament. (*b*) The coating of glow-lamp filaments with a layer of carbon, by heating them electrically in a hydrocarbon vapour.'—I.E.C.]

Filings Coherer. See COHERER, FILINGS.

Finger, Spacing. See SPACING FINGER; DISTANCE PIECE; DUCT, VENTILATING; VENTILATION OF ELECTRICAL MACHINERY.

Finger Die. See DIE.

Fingers (of a Controller or Switch), stationary contact pieces, usually pressed by springs against the contact pieces mounted on the movable part or parts.

Finishing Varnishes, air-drying varnishes, usually black, employed for giving a finished appearance after apparatus has been insulated and assembled. Varnishes for this purpose should give a hard, lustrous coat which will not soften with heat, or become brittle and crack with age. Their insulating properties need not be high, but they should be moisture-proof, withstand hot oil, and should be of a consistency suitable for application by spraying. See INSULATING VARNISHES; CORE-PLATE VARNISHES; FLEXIBLE MICA-STICKING VARNISHES.

Fire, Situations in which there is Danger of. See SITUATIONS IN WHICH THERE IS DANGER OF FIRE.

Fire Alarm. See ALARM, ELECTRIC.

Fire Alarm Telegraph System. See TELEGRAPH SYSTEMS.

Fireproof Covering.—This term should be applied to an insulating covering that is wholly incombustible, but it is often misapplied to a covering that is simply *fire-resisting*. See also NON-COMBUSTIBLE INSULATING COVERING; FIRE-RESISTING COVERING.

Fireproof Situations, defined by the V.D.E. (see Journ.I.E.E., vol xli, p. 167) as premises which cannot be ignited, or which, if ignited, cannot maintain combustion.

Fire-resisting Covering, a term applied to an incombustible covering surrounding an inflammable dielectric. In cases of fire it acts to some extent as a *fireproof covering*, since it retards the combustion of the inflammable dielectric, but it is erroneous to term such a covering *fireproof*. See also FIREPROOF COVERING; NON-COMBUSTIBLE INSULATING COVERING; DELTABESTON MAGNET WIRE; ASBESTOS; ASBESTOS WOOD; WIRE, ENAMEL-INSULATED; MICA; MICANITE; INSULATION, LAVA; AMBROIN.

Fire-test of an Oil. See OIL, FIRE-TEST OF.

First Charge of Accumulator. See ACCUMULATOR, FIRST CHARGE OF.

Fischer-Hinnen Method of Starting Induction Motors. See 'Special Methods of Starting Induction Motors' under STARTING OF MOTORS.

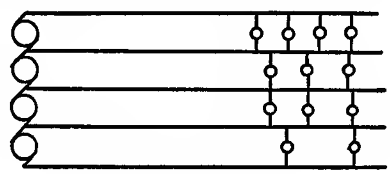
Fishpaper, a trade term for the thin, tough paper from which leatheroid is manufactured. See LEATHEROID.

Fishplate, a plate located at a rail joint, and by means of which the adjacent rails are bolted together.

Fish Wire. See WIRE, FISH.

Five-point Jack. See JACK, FIVE-POINT.

Five-wire System, an extension of the three-wire system (see THREE-WIRE DISTRIBUTING SYSTEM), in which three intermediate or neutral conductors are employed, as indicated in the fig. The system is now rarely used in this country. (Ref. 'Central Electrical Stations', C. H. Wordingham.)



Five-wire System

Fixed Resistances. See RHEOSTAT.

Flame Arc. See ARC.

Flame Arc Lamp. See LAMP, ARC.

Flame Carbons. See CARBONS, ARC-LAMP.

Flame Lighting, electric lighting by means of flame arc lamps. See LAMP, ARC.

Flanges, Stator. See CORE HEADS; END PLATES.

Flanges for Field Spools.—In order to protect the spools from mechanical injury by contact with the sometimes rough field castings, and also to afford a support when the depth of the winding exceeds the overlap of the pole shoe, flanges, often of cast brass, or other metal, but sometimes of moulded insulating material, are placed above and below the spool. In some cases the flange forms one piece with a frame of the same shape as the magnet pole, and the coil is permanently wound upon this frame.

Flank Dispersion. See DISPERSION, MAGNETIC.

Flash Point of an Oil. See OIL, FLASH POINT OF AN.

Flash Test of Insulation of Electric Machines.—A h pr test on a piece of electric apparatus is called a *flash test* when it is applied for a very short period, as opposed to a time test. The duration of a *flash* test may be from five sec or so, down to a fraction of one sec. Such tests are usually made at from five times normal rated pressure in l pr machines, to one and one-half times normal rated pressure in apparatus for very high pressure.

In the case of l pr continuous machinery, or the fields of alternators, a higher multiple is used, as the insulation used is more likely to suffer mechanical injury when in service, and should consequently be of ample proportions.

['*Flash Test of Insulation of Electric Machines.*—The momentary application of a high electrical pressure between two conductors insulated from each other.'—I.E.C.]

Flashing. See FILAMENT.

Flashing of Filament. See FILAMENT.

Flashing Over.—When a commutator is not kept clean, or when soft brushes are used, sparks are sometimes seen to pass between the brush and some segment situated some little distance away from the brush. Should this sparking be allowed to continue, it may ultimately result in an arc being started right across from one set of brushes to another, thus short-circuiting the machine and doing considerable damage to the brush-gear. A flash-over is sometimes originated by a short-circuit on the line, or by suddenly switching the machine off from the line when it is carrying full current. Either of these occurrences may momentarily induce a h pr across the machine, and may break down the surface of the insulation between the various commutator bars. Flashing over is the more liable to occur with machines with high reactance voltage (which see), or high average voltage between segments (which see), the latter being by no means the least important factor in interpole machines. The distortion of the magnetic flux may occasion a crest pressure between adjacent segments greatly in excess of the average pressure between segments.

['*Flashing Over*, the temporary formation of an arc from brush to brush on a commutator.'—I.E.C.]

Flat Bar on Commutator. See COMMUTATOR BAR.

Flat Coil. See COIL, FLAT.

Flat Compounding. See EXCITATION.

Flat-rate System. See TARIFF SYSTEMS.

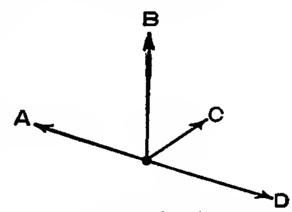
Fleming Cymometer. See CYMOMETER.

Fleming-Ediswan Large-bulb Standard Lamp. See LAMP, FLEMING-EDISWAN LARGE-BULB STANDARD.

Fleming Oscillation Valve. See RECTIFIER.

Fleming's Rule.—(*a*) To find the direction of the induced emf in a generator. Place the thumb and first two fingers of the right hand approximately in three directions at right angles to one another. Point with the first finger in the direction of the lines of force, and with the thumb in the direction of motion. The second finger then gives the direction of the induced emf.

(*b*) To find the direction of motion or of torque in a motor, use the left hand in a similar way, pointing the first finger in the direction of the field and the second in the direction of the current. The thumb then gives the required direction in which the conductor carrying the current tends to move (see fig.). See CURRENT, DIRECTION OF; AMPERE'S RULE; CORKSCREW RULE.



Fleming's Rule

A, Induced emf; generator current; back voltage of motor. B, Motion. C, Flux. D, Motor current.

Flexible. See CABLE, FLEXIBLE.

Flexible Cable. See CABLE, FLEXIBLE.

Flexible Conduit. See CONDUIT, UNDERGROUND.

Flexible Coupling. See COUPLING, FLEXIBLE; OLDHAM'S COUPLING; COUPLING, SHAFT; INSULATING COUPLINGS; CLUTCH.

Flexible Mica, thin mica sheet built up of very thin laminæ, and of a plastic cement which allows the requisite amount of play between the overlapping laminæ without preventing the continuity of mica. It is in no way a substitute for a built-up mica plate, and, wherever possible, it is preferable to mould mica-plate to the desired shape. Its chief use is for the insulation of armature conductors.

The manufacturers of built-up mica plate sold under the various trade names supply lines of flexible mica the insulating properties of which depend on the method of manufacture and on the adhesive material employed. See MICA; MICANITE; MEGOHMIT. (Ref. 'The Insulation of Electric Machines', chap. v, Turner and Hobart.)

Flexible Mica-sticking Varnishes.—These are employed for the manufacture of flexible mica, mica cloth, mica paper, &c. They must be air-drying varnishes with good adhesive powers, and of a thin consistency, to reduce the amount of varnish between laminæ to a minimum. Their insulating properties need not be high, but they should be flexible and moisture-proof, and they should not soften at a low temperature. See also MICA-STICKING VARNISHES.

Flexible Suspension, a means of suspending an overhead trolley line so that there shall be a minimum of shock at the joints when the trolley passes.

Flexible Wiring Systems. See WIRING SYSTEMS.

Flicker Photometer Head. See PHOTOMETER HEAD, FLICKER.

Floating Ring. See RING, FLOATING.

Floor Insulator. See INSULATOR.

Fluctuating Demand. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Fluid Insulator. See INSULATOR.

Fluorescence. See RADIATION.

Fluorescence Light. See LAMP, TUBULAR.

Fluorescent Screen.—Radiations which may be invisible or only faintly visible may, when allowed to fall on certain substances, excite a secondary radiation which is much more stimulating to the eye or photographic plate or other detector.

Of especial use in detecting Röntgen Rays are crystals of barium platinocyanide, which emit a brilliant greenish light when acted upon by the rays. For convenience they are generally sprinkled on an adhesive parchment surface stretched on a wooden frame, which is known as a *fluorescent screen*. See 'Fluorescence' under RADIATION.

Flush.—Switches and other electric fittings are frequently arranged to be recessed into the wall or ceiling, so that the surface is substantially in the plane of the wall or ceiling. Such fittings are termed *flush fittings*. Thus there are *flush plugs* and *flush switches*. Such method of installation is broadly termed *flush work*. In *semi-flush work* the material projects beyond the surface of the wall or ceiling. *Surface fittings* stand right out on the surface of the wall or ceiling.

Flush Plug. See FLUSH.

Flush Switches. See FLUSH.

Flush Work. See FLUSH.

Flux, Alternating, a magnetic flux which alternates; the magnetic flux produced in iron by an alternating mmf; as that produced by ac in windings in or about a laminated mass of iron.

If an alternating flux, having a frequency equal to ~ and with a crest value of M, be established in a coil of T turns, it induces in that coil an alternating emf of $\frac{2\pi \sim MT}{\sqrt{2}}$ effective volts. This applies to all windings in which alternating flux occurs, as in all ac machines, and in armatures of cc machines. See ALTERNATING.

Flux, Armature, the total number of lines of magnetic flux which finally enter the armature core from each magnet pole, and become linked with the armature winding.

ARMATURE LEAKAGE FLUX is that part of the magnetic flux due to the current in the armature conductors which is linked with the armature turns only. See FLUX, LEAKAGE.

Flux, Auxiliary. See AUXILIARY FLUX.

Flux, Leakage, that portion of the magnetic field which encloses one only of the two windings (primary and secondary) of a dynamo-electric machine.

In cc machines the term is usually applied only to that portion of the magnetic flux which does not cut the armature conductors, but leaks back through various paths, *e.g.* from pole shoe to pole shoe, or from pole shoe to magnet yoke, without entering the armature iron.

The total magnetic flux passing through the magnet cores can therefore be divided into *useful flux*, which cuts the armature conductors, and *leakage flux* (also called *stray flux*, *leakage field*, and *stray field*), which does not cut the armature conductors.

That coefficient by which the *useful flux* must be multiplied in order to obtain the total flux is called the *leakage factor*; it varies in different types of cc machines from about 1·1 to 1·4, or sometimes even more.

In ac motors and in transformers the term *leakage flux* is applied both to the field enclosing the primary winding only, and to the field enclosing the secondary winding only.

See FLUX, ARMATURE; MAGNETIC LEAKAGE; DISPERSION, MAGNETIC.

Flux, Magnetic (M), the flux of magnetic induction, a term used to describe the state of magnetisation of a magnetic circuit. It depends on the flux-density and the cross-sectional area through which this flux-density exists. In cases where the magnetic flux-density is not constant, the total magnetic flux is obtained by summing up the product of flux-density and area over the whole area, $M = \int B\,dA$. See UNIT OF MAGNETIC FLUX; INDUCTION, MAGNETIC; FIELD, MAGNETIC.

Flux, Pulsating Stator, a variable magnetic flux superimposed on the main flux of an induction motor, and due to the periodic variations in the magnetic reluctance due to the different relative positions successively occupied by the stator and rotor teeth.

Flux, Remanent, the number of unit magnetic lines remaining in a magnetic circuit when the magnetising force is removed. This flux is large, both with soft iron and steel, when the magnetising force is removed without vibration, and when no demagnetising force, such as that arising from a pole, occurs. With soft iron this remanent flux is very easily removed by vibration, but with hard steel the remanent flux is permanent, and is known as *permanent magnetism.*

Flux, Resultant, a magnetic flux due to two or more mmf, and which, for practical purposes, may sometimes conveniently be considered as resulting from the combination of the magnetic fields respectively due to each mmf.

Flux, Rotating, the magnetic flux arising from a rotating magnetic field. It may be provided either by revolving magnet poles (see 'Revolving-field Type of Alternator' under ALTERNATOR), or by a fixed polyphase winding. See THREE-PHASE ROTATING MAGNETIC FIELD; FIELD, ROTATING.

Flux, Superposed, an imaginary magnetic flux supposed to exist in conjunction with the main flux, and combining with it to give the actually present resultant flux. See FLUX, RESULTANT.

Flux Density. See INDUCTION DENSITY.

Flux Distribution, the distribution of magnetic flux density across any section of a magnetic circuit; a term applied generally to the flux distribution over a pole face, or in the air gaps of electrical machinery.

Fluxmeter (Grassôt). See GRASSÔT FLUXMETER.

Flywheel, Kinetic Energy of. See ENERGY, KINETIC, OF FLYWHEEL.

Flywheel Storage, the storage of energy in kinetic form in a flywheel designed for the purpose. The object of the usual engine flywheel is to obviate rapid fluctuations of speed, due to load-variations or other causes. This result is attained by means of the kinetic energy stored in the flywheel, but the term *flywheel storage* is more usually applied to systems combining electrical machines and heavy flywheels designed for operating on loads of very fluctuating and intermittent character. In such cases the object of the flywheel is not necessarily to maintain constant speed, as in the above-mentioned case, but to store up and give out a required amount of energy while the speed varies through a given predetermined range. During times of light load the flywheel is caused to accelerate and thus store energy, and during periods of heavy load the flywheel is allowed to slow down, delivering a portion of its energy as useful work.

Flywheel storage is frequently employed in connection with electrically-operated haulage, hoisting, and similar schemes, and sometimes for heavy electrically-driven shearing and punching machines and the like, and for rolling mills. See 'Ilgner System' under MINING EQUIPMENT, ELECTRICAL.

Flywheel-type of Alternator. See ALTERNATOR; MAGNET-WHEEL.

Fool-proof, a term applied to those types of motor starters and switches which possess means for preventing the resistance of the starter from being cut out too quickly. The device often consists of some form of dashpot or reduction worm-gear, the action of which retards any quick movement of the starting handle, and thus prevents the operator from moving it quickly over the resistance contacts. Interlocking mechanisms applied to switch gear, and arranged, for instance, to prevent a certain switch from being opened or closed until some other switching operation has been completed, also come under this designation. Apparatus may be termed *fool-proof* to the extent to which its operation is rendered practically independent of any mental aberrations of the operator, *i.e.* to the extent to which the element of human fallibility is eliminated. See LOCKING DEVICE; SWITCH, INTERLOCKING; STARTING OF MOTORS.

Foot Bond. See BOND.

Footstep Bearing. See BEARINGS.

Force, that which changes the motion of, or tends to change the motion of, matter. Force is measured by the change of motion per unit mass of matter that it produces or is capable of producing. In the cgs system (which see) the unit of force is called the *dyne*, this being the force which is capable of producing, in a mass of 1 g, a velocity of 1 cm per sec per sec of action. Other units of force in common use are the *lb* and the *kg*, being respectively equal to the weights of these masses.

The word *force* is used in the electrical and magnetic sciences in a sense distinct from the above. Thus *electric force* is the force which a system of charged bodies would exert on an infinitesimal body charged with a unit of electricity, on the supposition that the charges of the system are not disturbed by the unit charge. Electric force is therefore not a true force, but a force per unit charge of electricity. It is accordingly sometimes called *electric intensity*. Electric force or electric intensity exists within the region where the charged bodies have influence, whether the unit charge is present or not, in this respect again differing from true force, which requires the presence of matter. The above remarks apply also to *magnetic force*, or *magnetic intensity*, which is a force per unit magnetic pole.

Electromotive force again is quite distinct from true force, being in certain cases the line integral of the electric force (see ELECTROMOTIVE FORCE). Similarly magnetomotive force is the line integral of the magnetic force. See MAGNETOMOTIVE FORCE.

[F. W. C.]

Force, Electric. See FORCE.

Force, Electromotive. See ELECTROMOTIVE FORCE; FORCE.

Force, Electrostatic, force due to the interaction of electrical charges at rest. See LINE OF INDUCTION; FIELD, ELECTROSTATIC.

Force, Magnetomotive. See MAGNETOMOTIVE FORCE; FORCE.

Force, Unit of. See FORCE.

Forced Commutation. See COMMUTATION.

Forced Lubrication. See BEARINGS.

Forced Ventilation. See VENTILATION OF ELECTRICAL MACHINERY.

Forged Steel for Magnets. See STEEL.

Form Factor, a term introduced by Fleming, which denotes the ratio of the *effective* or *rms* value of an alternating wave to its true mean value. For a sine wave the rms value is $\frac{1}{\sqrt{2}}$ times the maximum, and the mean is $\frac{2}{\pi}$ times the maximum, so that the form factor is $\frac{\pi}{2\sqrt{2}}$ or 1·11. The induction wave which generates an alternating emf wave has a maximum value proportional to the area, *i.e.* to the *mean* value of the emf wave. Hence the induction values corresponding to two emf waves whose rms values are equal will be inversely proportional to their form factors. This is illustrated by the fact that a *peaked* wave causes less hysteresis loss in a transformer core than a flat-topped wave, owing to the higher form factor of the peaked wave.

Form-wound Coil. See COIL, FORM-WOUND.

Former. See WINDING, FORMING, AND SPREADING MACHINERY.

Forming Positive Plates of Accumulators. See ACCUMULATOR PLATES; ACCUMULATOR.

Forward Lead.—The brushes of a generator are sometimes displaced in advance of the neutral position. They are then said to have a *forward lead.* See BRUSHES, ADJUSTMENT OF; 'Angle of Forward Lead' under ANGLE OF LEAD.

Foucault Currents. See EDDY CURRENT.

Foundation Plate.—In large engine-driven machines where the set is not provided with a complete bedplate, the machine is supported upon separate castings a little larger than the feet of the machine, these being set in the concrete when the foundations are laid. Also known as *sole plates.* See BED BLOCKS; BEDPLATE.

Fourier's Method.—Fourier, in his 'Analytical Theory of Heat', developed a mathematical method for the study of the flow of heat which has since been found (by Lord Kelvin) to be applicable to many other important questions in which the idea of flow is present. His principal law may, in its simplest form, be expressed by the equation $\frac{dv}{dt} = k\frac{dv^2}{dx^2}$; where v is temperature, t is time, and x distance. In words it may be stated as: The time rate of change of temperature at a point (in a conductor) is proportional to the space rate of change of the gradient of temperature. Kelvin showed that, in addition to temperature, v may represent density of material in molecules (*e.g.* of diffusion of salts through liquids), diffusion of viscous motion in a liquid, diffusion of electric current in a conductor, and other types of diffusive motion. In solving the problem Fourier discovered that great mathematical theorem which goes by his name, viz. *Fourier's theorem*, which is to the effect that any curve may be represented by a series of sines and cosines with properly chosen coefficients. This theorem is of immense use in all branches of physics, especially where periodic motions occur, since by its means the curve may be analysed into a number of simple harmonic or sine curves of different periods. Machines have been constructed by Kelvin, Henrici, and others, in which the analysis is performed mechanically. See HARMONIC; FUNDAMENTAL WAVES AND THEIR HARMONICS.

Fourier's Theorem. See FOURIER'S METHOD.

Fourth Rail. See note at end of definition of THIRD-RAIL ELECTRIC RAILWAY.

Fourth Wire.—This expression generally refers to a conductor connected to the neutral point of a three-phase system. The pressure between the fourth wire and each of the outers is approximately $\frac{1}{\sqrt{3}}$ of the pressure between any two outers, and hence, if lamps, &c., are connected to the fourth wire a higher pressure is permissible between the outers, and a reduction is effected in the total amount of copper required, somewhat in the same way as with a three-wire cc system. The fourth wire is generally of smaller area than the outer conductors since if the loads on the three sides are equally balanced, the fourth wire has no current to carry. See FOUR-WIRE STAR CONNECTION. (Ref. 'Electrical Engineers' Pocket Book'; 'Standard Polyphase Apparatus and Systems', Oudin.)

Four-wire Star Connection refers to the connection of a three-phase winding or circuit where a fourth wire is connected to the neutral. A system connected in this way is sometimes used for lighting work, the lamps being connected between outers and neutral. See FOURTH WIRE

Four-wire System, a system of distribution in which four wires are employed. The term is usually applied to a two-phase system where the phases are kept separate, as against the case where one of the wires is common to both phases. See TWO-PHASE SYSTEM.

Fractional-pitch Winding. See WINDING, FRACTIONAL-PITCH.

Frahm's Vibrating-reed Frequency Meter. See 'Resonance or Tuned-reed Pattern' under FREQUENCY INDICATOR OR METER.

Frame, Magnet. See MAGNET FRAME.

Frame, Resistance. See RHEOSTATS OR RESISTANCES.

Frame, Split.—In very large dynamo-electric machines the frame or carcass is built in halves with a view to facilitating manufacture as well as transport. For special reasons split frames are also frequently employed in small machines. In large machines the two halves are usually divided either on the horizontal diameter or on a chord parallel to, but below, the horizontal diameter. Occasionally, however, the frames of large cc machines are divided on a vertical diameter.

Frame, Standard.—A machine for a given output will require different sizes and numbers of conductors on the armature and field, according to the pressure, speed, and other details of the specifications. Within limits, however, the main dimensions of the machine may in many cases remain the same, and it is therefore the practice with large firms to have a set of standard sizes of frames or carcasses which are kept in stock in a more or less finished condition, ready to receive a set of windings suitable for individual requirements.

Frame, Stator, the skeleton casting or structural member which forms the mechanical support for the core plates of the stationary portion of alternators and induction motors. It is preferably of an open pattern in order to allow the heat of the core to escape freely. On the inside, the frame is provided longitudinally with webs in which keyways are cut to receive the core plates. The frame is also sometimes spoken of as the *stator spider*, a term originating from the time when alternators with internal rotating armatures were the general practice. For a full discussion of the design of stator frames see Dr. Thompson's 'Dynamo-electric Machinery', vol. ii, p. 181, &c., and Rushmore, Trans.

A.I.E.E., vol. xxi, 1904. The following are some of the different forms of construction:—

GIRDER-TYPE.—This type of frame has been employed by the Siemens-Schuckert Company, and consists of boiler-plate and channel-iron built up by riveting and bolting into suitable box-like sections to give the requisite stiffness. Fig. 1 gives a typical example of this type of frame, which, it will

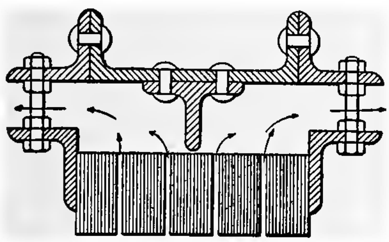


Fig. 1.—Girder-type Stator Frame

be seen, is very light compared with cast-iron types of frame.

TIE-ROD TYPE.—In this type of frame very light cheek castings are used to form a mechanical support for the stampings. In order to obtain the requisite stiffness, tie-rods, capable of adjustment, are arranged to stretch across segments of the frame. A good example of this type of frame is to be seen in the large alternators supplied by the Allgemeine Electricitäts-Gesellschaft to the Manchester Corporation. (Ref. Lasche, Eng. vol. lxxii, p. 173, 1901.)

BOX-TYPE.—Fig. 2 shows a form of box frame used on large slow-speed machines.

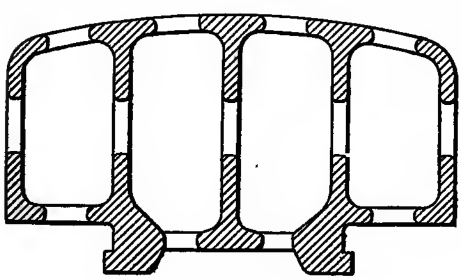


Fig. 2.—Box-type Frame

More often, a single box is used, but in the larger sizes extra ribs are necessary to obtain greater side-stiffness with a reasonable depth.

CHEEK-TYPE.—This type of stator frame depends for its strength upon the depth of the end shields or cheeks, which are cast in one with the back support of the punchings, see fig. 3. It is a form which has been used considerably on the Continent, and has the drawback that the machining of the fixed flange at A and the set-groove for the re-

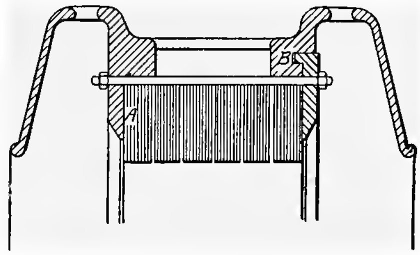


Fig. 3.—Cheek-type Frame

movable flange at B is attended with difficulties and expense. [H. W. T.]

Free Handle, a handle so arranged upon a circuit breaker, for the purpose of closing the circuit after it has been interrupted, that if the conditions on the circuit are still such that the circuit ought not to be closed, it will be impossible to maintain it closed (more than momentarily) by operating the handle.

Free Length of Winding. See EMBEDDED LENGTH OF WINDING.

French Chalk for Assembling Core Plates.—French chalk is a variety of talc, of a white or greenish-grey colour. It is an extremely soft mineral, and can be reduced to a very fine powder. In this condition it has a soft, smooth feeling, and is used as a dry lubricant. It has a high resistance, and if dusted on varnished core plates before the varnish is quite firmly dried, the French chalk will serve to increase the resistance of the varnish film, without appreciably increasing the thickness. See also TALC.

French Wire Gauge. See WIRE GAUGE.

Frequency.—

['*Frequency.*—The number of complete periods per sec of an ac.'—I.E.C. The Committee adds: 'The term *periodicity* is not recommended'. The Committee endorses ~ as the symbol for *frequency*.]

See also ALTERNATING CURRENT; ALTERNATING-CURRENT SYSTEM; PERIODICITY.

Frequency, High (preferable abbreviation = hf), a term used chiefly in *wireless telegraphy* and *wireless telephony* for electricity at periodicities of 10,000 cycles per sec and upwards.

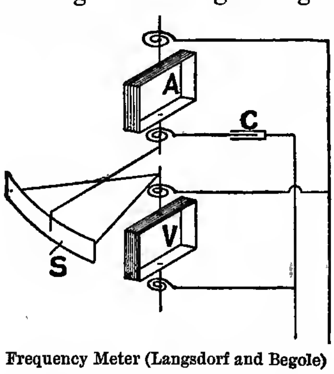
Frequency, Low (preferable abbreviation = lf.) In a relative sense *all* cases of the application of alternating electricity in power and lighting are carried out at lf, but the term lf has come to denote periodicities of not over 25 cycles per sec. Periodicities of only 15 cycles per sec are now coming into use on the Continent and in America for sp railways.

Frequency-changer, a machine used for changing the frequency of alternation of an electric current. One form consists of a synchronous alternating motor, which runs at a constant speed corresponding to the frequency of the current supplied, driving an alternator which generates electricity at the frequency which it is desired to obtain. In another form of frequency-changer the electricity of the original frequency is sent into the primary member of a structure practically identical in all respects with a wound induction motor (which see), and electricity of the required frequency is obtained from the secondary member. The amount of the alteration of frequency is dependent upon the speed of the rotor of this machine, which is driven by a motor. A frequency-changer is sometimes termed a *frequency-converter.* See CONVERTER.

Frequency-converter. See CONVERTER; FREQUENCY-CHANGER.

Frequency Indicator or Meter, an instrument for the measurement of frequency. The commonest forms are:

1. The INDUCTIVE-CIRCUIT PATTERN, in which the indications depend on the variations occurring in the magnetising current



Frequency Meter (Langsdorf and Begole)

in an inductive circuit, as the frequency is changed.

2. The LANGSDORF AND BEGOLE FREQUENCY METER, which is based on the fact that if an alternating emf of E volts is impressed on a condenser of capacity C in farads, the frequency being $\sim$, the current in amp will be equal to $2\pi \sim EC$, provided the pressure is constant. In the fig. A is the current coil, C the condenser, and S is the scale mounted on the same axis as the volt coil V, across the mains, so as to render the instrument independent of variation of emf. (See Elec. Rev., vol. lviii, p. 114.)

3. RESONANCE OR TUNED-REED PATTERN of frequency meter. The *Frahm* frequency meter is of this type. It is based upon the principle that a pendulum of a given length will duly respond to periodic forces having the same time period as itself. The instrument comprises a number of reeds, all having different lengths, mounted in a row, and all subject to the pulsating attraction of an electromagnet excited by the ac. That reed which has the same time-period as the current will vibrate, while the others will remain at rest. (See Elec. Rev., vol. lix, p. 363, and p. 1085 of Elec. Eng. for Dec. 23, 1909.)

Frequency Meter. See FREQUENCY INDICATOR OR METER.

Frequency of Alternation. See ALTERNATING CURRENT; ALTERNATING-CURRENT SYSTEM; FREQUENCY.

Frequency of Commutation. See COMMUTATION.

Fricker Maximum-demand Indicator. See INDICATOR, MAXIMUM-DEMAND.

Friction, Bearing. See BEARING FRICTION IN DYNAMOS AND MOTORS.

Friction and Windage Loss. See LOSS, FRICTION AND WINDAGE.

Friction Clutch. See CLUTCH.

Friction Coefficient.—The force required to move two surfaces in contact against the friction existing between them is found in practically all cases to be directly proportional to the pressure between the surfaces. The ratio between the force required to overcome friction and the pressure between the surfaces is generally denoted by the Greek letter μ, and is called the *coefficient of friction.* The ratio is of particular interest to electrical engineers in connection with the brush friction losses on commutators and slip rings. The following approximate figures may be given for the typical cases found in practice:—

Copper brushes	... ...	0·2
Carbon „	... ...	0·3
Graphite „	(such as morganite)	0·2

Frequently a commutator is wiped with paraffin wax or oil in order to reduce the friction, and Baily (Journ.I.E.E., vol. xxxviii, p. 160) has found that, while the presence of these lubricants in small quantities produces a marked diminution in the friction, it need not, under suitable conditions, appreciably affect the *contact voltage.*

To calculate the loss due to friction, the following formula should be used:—

$$\text{kw} = \frac{P \times \mu \times s \times 33{,}000}{746},$$

where P = total pressure in lb on all the brushes per commutator or per set of slip rings; and s = peripheral speed of commutator or rings in ft per min.

It may be pointed out that while an increase in pressure increases the friction loss, it slightly decreases the I^2R contact loss, and that for a given brush density there is, therefore, one pressure which will give a minimum total loss. Makers naturally recommend the particular pressure at which their own brushes work best. [H. W. T.]

Friction Compensation for cc Energy Meters. See Coil, Compounding; Coil, Compensating.

Friction Compensation in Induction Meters. See Meter, Cc Watt-hour Motor; Meter, Friction Compensation in an Induction.

Friction Gear. See Gearing for Electric Motors.

Friction Tape, a heavy drill or canvas, impregnated with rubber or other suitable insulating compound, cut into widths from ½ to 1½ in, and used for insulating wires at joints or other exposed places.

Frictional Electricity.—It is true, in general, that any two different substances will, when rubbed together, become electrified. If the materials are conductors, they must be mounted on insulating stems to preserve the charge till tested. The discovery of electricity was due to this phenomenon, and its name is taken from the Greek *electron,* meaning amber, which substance is easily electrified by rubbing it on fur or wool. Glass becomes positively electrified when rubbed with silk, and sealing wax and ebonite become negatively electrified when rubbed with fur or flannel. Other materials are mostly intermediate between these. Friction of unlike bodies is not an economical way of producing electricity, as by far the greater proportion of the work done is wasted as heat. It has, therefore, never been adopted in practice, except where very small quantities of electricity of very h pr are required. See Frictional Electric Machine.

Frictional Electric Machine, a generator of continuous electricity acting by the natural pd of solids (contact potential), inducing charges whose pressure is raised by change of capacity caused by relative motion of the rubbing surfaces. Such machines are very inefficient, and are of extremely small output. It is, however, easy to obtain h pr by their means. See Machine, Wimshurst; Machine, Holtz Influence.

Frictional Heating.—In electrical machinery the principal frictional heating is that due to the friction of the bearings, and that of the brushes at the commutator or collector. The total losses from these causes are, however, usually small compared to the other losses. See Friction Coefficient; Bearing Friction in Dynamos and Motors; Loss, Friction and Windage.

Fringe of Flux.—In order that the flux shall not end abruptly where the pole face ends, the pole tip or horn is sometimes rounded off, so that a more gradual change in the flux distribution shall take place. This tapering-off of the flux is often spoken of as *fringing.* See Eccentric Pole Face.

Fringing Coefficient. See Gap Reluctance.

Fringing of Magnetic Field. See Gap Reluctance.

Frog, a device used at the junction of two converging trolley wires, serving the same purpose in the overhead construction as the points in the track. On converging lines the frog has a fixed tongue, but where the lines diverge a movable tongue is provided, which may be controlled by a wire from the side of the road, to permit of guiding the trolley wheel in the desired direction.

['*Frog,* in tramway overhead work, a fitting uniting two diverging trolley wires with a single wire (*a*) provided with a spring tongue, or (*b*) pull-over tongue, or (*c*) of the fixed type.'—I.E.C.]

Front Pitch. See Winding Pitch.

Frosted Globe. See Globe.

Ft, the preferable abbreviation for feet or foot.

Ft lb, the preferable abbreviation for foot pound.

Fuel, Calorific Value of. See Calorific Value.

Fuel Consumption, the amount of fuel burned, preferably expressed in *kg* per kelvin (*i.e.* per kw hr) of output from an electric generating set or from an electricity supply station. A statement of the fuel consumption is of but little interest unless accompanied by knowledge of the calorific value of the fuel. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Fuller Battery. See BATTERY, PRIMARY.

Fullerboard, sometimes termed *press-spahn.* Fullerboard resembles press-spahn in appearance, but usually contains less moisture, and is more uniform in dielectric strength. It is a tough, fibrous material, and is used where its mechanical properties render it suitable. See PRESS-SPAHN.

Full Excitation. See EXCITATION, FULL.

Full Load, the normal load for which a dynamo or other apparatus is designed; the load defined by the specification as the normal load of the machine.

Full-load Characteristic, the curve showing the relation between the terminal pressure of any generator and the current flowing in the exciting circuit when the generator is giving full-load current. See CURVE, CHARACTERISTIC.

Full-load Efficiency. See EFFICIENCY.

Full-pitch Winding. See WINDING, FRACTIONAL-PITCH.

Fundamental denotes that component of a non-sinuous ac or emf wave whose frequency is the fundamental or principal frequency of the system. Except in cases of very abnormal distortion, the fundamental component has an amplitude many times greater than the amplitudes of the harmonics. See HARMONIC.

Fundamental Units. See UNITS, FUNDAMENTAL.

Fundamental Waves and their Harmonics.—If $f(x)$ represents any single-valued periodic function of x, and if λ be the period, *i.e.* the value of x at which the values of $f(x)$ begin to recur, $f(x)$ may be expressed in the form:

$$A_0 + A_1 \sin\left(\frac{2\pi x}{\lambda} + e_1\right) + A_2 \sin\left(\frac{4\pi x}{\lambda} + e_2\right) + A_3 \sin\left(\frac{6\pi x}{\lambda} + e_3\right) + \&c.,$$

where A_0, A_1, A_2, A_3, e_1, e_2, e_3 are constants.

The second term of the series is the *fundamental term,* the third term is called the *first harmonic,* the fourth term the *second harmonic,* and so on. In alternating systems the emf, currents, &c., usually vary with time in a periodic manner. If r be the periodic time of the variation, or the reciprocal of the frequency, the emf or current wave may be split up into a number of sinusoidal components of ascending frequencies. Thus it may be considered to comprise a fundamental term of (fundamental) frequency $\frac{1}{r}$, together with the terms involving double, triple, quadruple, &c., frequencies.

Terms involving twice, four times, and any even number of times the fundamental frequency, as also a constant such as A_0 in the expression given above, result in a dissimilarity of form of the positive and negative halves of the wave, and such terms are frequently absent. See also HARMONIC; FOURIER'S METHOD.

Furnace, Electric.—Electric furnaces may be divided broadly into two classes. Firstly, those in which the current is utilised to fuse the contents of the furnace, and then to complete the process by electrolytic action, and secondly, those in which the current is used exclusively for heating, no electrochemical action taking place.

The most important furnaces of the first class are those of Héroult for the manufacture of aluminium, in which alumina is electrolysed in a bath of fused fluorides.

The second class, which are in more general use, may be subdivided into (1) those in which resistance heating is used; (2) those in which the arc is used, the material operated upon being in the arc circuit; (3) those in which the arc is used, the material operated upon being outside the circuit, and so being subjected to the radiant heat from the arc; and (4) induction furnaces.

In the ACHESON CARBORUNDUM FURNACE the heating is due to resistance only. Referring to fig. 1, C is a central core of coke which provides a path for the current and becomes heated by its passage. D D is an outer packing of sand and coke which is reduced to carborundum by the heat evolved in C. A is a carbon paste for the purpose of providing

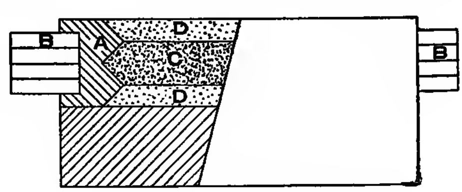


Fig. 1.—Acheson Carborundum Furnace

a good contact between C and the carbon blocks B, to which the conductors from the dynamo are connected.

As shown in fig. 2, the HÉROULT FURNACE for iron and steel acts as an arc furnace, the current passing from one electrode to the

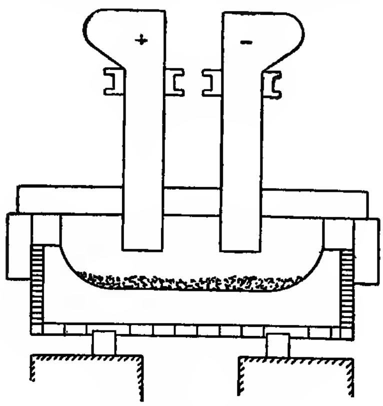


Fig. 2.—Héroult Furnace

surface of the metal and forming one arc, and on the other side of the furnace passing from the surface of the metal to the other electrode, forming a second arc. If resistance heating is required, the electrodes are lowered into the metal. The bottom of the furnace is curved, so that it can be tipped for the purpose of pouring the metal.

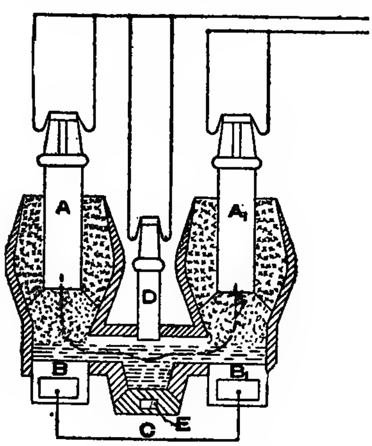


Fig. 3.—Keller Furnace

The KELLER FURNACE, for iron smelting (fig. 3), is of the resistance type. A A_1 are the two electrodes around which is placed the mixture of iron ore, coke, and lime. When the current is first switched on, it passes from A to B, through the conductor C to B_1 and thence to A_1. As the melted metal accumulates in the bottom of the furnace, the current passes from A to A_1 through the metal, as shown by the dotted line. Supplementary electrodes D E are provided, which can be brought into action if the circuit is broken on either side of the furnace.

In the STASSANO REVOLVING FURNACE the electrodes do not come in contact with the metal, which is heated by radiant heat from the arc. The furnace is slightly inclined, and is provided with bearings at the top and bottom, so that, as it revolves, the contents are thoroughly mixed.

In the KJELLIN FURNACE the metal forms the secondary winding of a transformer, so

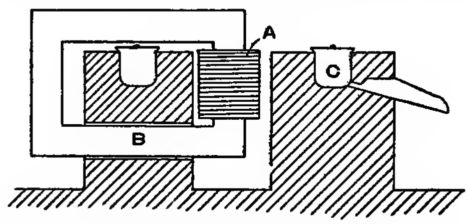


Fig. 4.—Kjellin Induction Furnace

that the current which produces the heat is generated by induction in the metal itself. Thus, electrodes are dispensed with, and it is claimed that an extremely pure metal can be produced.

Referring to fig. 4, A is the primary coil, which is connected to the supply mains. B is the magnetic circuit of the transformer, the secondary circuit of which is formed by the metal C in the furnace. In order to start the furnace it is usually necessary to pour in a small quantity of melted metal to provide a continuous conductor. (Ref. 'The Electric Furnace', Kershaw; 'Electric Furnaces and their Industrial Application', Wright; 'Electric Furnaces', Borchers; 'The Electric Furnace', Moissan.) [C. W. H.]

Fuse.—

['*Fuse.*—The actual wire or strip of metal in a cut-out, which may be fused by an excessive current.'—I.E.C.]

A fuse is a conductor of such proportions that it will fuse should the current in the circuit exceed a pre-arranged value, and so protect the rest of the circuit from any harm resulting from an undue overload. Fuses are generally of tin, copper, silver, or lead, or alloys of these, tin being perhaps most often employed. Copper has the advantage that it is less liable to mechanical injury, except when of very small section. but its melting temperature is high, while though silver is otherwise a suitable material, it is expensive, and lead has the disadvantage that it is very soft and liable to be accidentally altered in area. The accompanying table, deduced from data given by Preece, gives the fusing currents for different sizes of wires of various materials.

TABLE SHOWING CURRENTS REQUIRED TO FUSE WIRES OF VARIOUS SIZES AND MATERIALS

	Diameter, mm.	Cross Section, sq mm.	Copper.	Aluminium.	Platinum.	German Silver.	Platinoid.	Iron.	Tin.	Tin-lead Alloy.	Lead.
Current Density in Amp per sq cm.	0·25	0·049	225·0	163·5	122·5	122·5	102·0	81·6	40·8	24·5	32·5
	0·30	0·064	219·0	156·0	109·5	109·5	94·0	78·2	39·0	28·0	31·3
	0·40	0·125	160·0	120·0	80·0	84·0	76·0	52·0	32·0	20·0	23·0
	0·50	0·196	148·0	107·0	71·5	75·0	66·4	46·0	25·5	16·3	19·5
	0·60	0·282	133·0	100·0	67·5	69·0	62·0	42·5	21·3	15·3	17·7
	0·70	0·385	125·0	91·0	62·4	62·4	57·0	39·0	19·5	14·3	15·6
	1·00	0·78	103·0	74·5	51·4	52·5	47·5	32·0	16·7	12·8	14·0
	1·25	1·22	94·0	67·3	47·0	47·0	42·6	28·7	14·8	11·5	12·3
	1·60	2·0	83·5	60·0	41·5	41·8	38·0	25·5	13·0	10·5	11·0
	2·0	3·14	71·7	53·0	36·6	37·0	33·0	22·3	11·5	9·4	9·8
	4·0	12·6	50·8	38·0	25·6	26·0	23·6	15·6	8·1	6·55	6·85
	6·0	28·3	41·5	31·0	21·2	21·4	19·5	12·9	6·7	5·4	5·65
	8·0	50·3	36·0	27·0	18·0	18·2	16·5	10·7	5·7	4·57	4·8
	10	78·7	32·2	24·0	16·3	16·4	14·9	9·85	5·15	4·15	4·35
	12	113·2	28·4	22·0	14·9	15·0	13·7	9·1	4·7	3·80	4·00
	14	154·0	27·0	20·0	13·7	13·9	12·7	8·4	4·35	3·5	3·70
	16	201·0	25·5	19·0	13·0	13·2	12·0	7·9	4·12	3·32	3·50
	18	255·0	24·0	18·0	12·0	12·2	11·1	7·3	3·85	3·06	3·20
	20	314·0	23·0	17·0	11·5	11·6	10·5	7·0	3·63	2·92	3·07
	22	381·0	22·0	16·0	11·1	11·3	10·2	6·8	3·53	2·84	2·98
	24	453·0	21·0	15·4	10·5	10·65	9·7	6·4	3·34	2·70	2·80
Current in Amp per Conductor.	0·25	0·049	11	8	6	6	5	4	2	1·2	1·6
	0·30	0·064	14	10	9	7	6	5	2·5	1·8	2·0
	0·40	0·125	20	15	10	10·5	9·5	6·5	4·0	2·5	2·9
	0·50	0·196	29	21	14	14·7	13	9	5·0	3·2	3·8
	0·60	0·282	37·5	28	19	19·5	17·5	12	6·0	4·3	5
	0·70	0·385	48	35	24	24	22	15	7·5	5·5	6
	1·0	0·78	80	58	40	41	37	25	13	10	11
	1·25	1·22	115	82	57	57	52	35	18	14	15
	1·60	2·0	167	120	83	83·5	76	51	26	21	22
	2	3·14	226	167	115	116	104	70	36	29·5	31
	4	12·6	640	437	323	327	297	197	102·5	82·4	86·5
	6	28·3	1170	870	600	605	550	364	190	152·5	160
	8	50·3	1810	1340	905	915	830	550	287	230	242
	10	78·7	2530	1870	1280	1290	1170	776	405	325	342
	12	113·2	3320	2460	1685	1700	1550	1025	532	430	450
	14	154·0	4200	3100	2120	2140	1950	1290	672	540	567
	16	201·0	5130	3800	2610	2640	2400	1590	825	665	700
	18	255·0	6100	4520	3070	3100	2820	1865	970	780	820
	20	314·0	7170	5300	3600	3640	3310	2190	1140	918	964
	22	381·0	8250	6100	4250	4300	3900	2580	1345	1080	1135
	24	453·0	9450	7000	4770	4820	4380	2900	1510	1215	1275

The current at which a fuse melts may be largely altered by the size and shape of the terminals; if these are large and near together, the conduction of heat from the fuse may considerably raise the fusing-point. For this reason it is well to have no fuse less than 1 to 1½ in (25 to 38 mm) long even for 1 pr currents of less than 5 amp, while for currents greater than 5 amp an increased length should be given. For currents of 25 amp and upwards fuses should be, in general, of strip material and not of wire. It is doubtful if they should, under any circumstances, be used for currents of more than, say, 600 amp, as they then become unwieldy, and the molten metal may be a source of danger. Indeed, in many cases it is preferable to employ automatic circuit breakers for currents very much smaller than this, more particularly where there are likely to be frequent overloads, as on a tramway circuit, where the continual renewal of a fuse would be a troublesome and expensive matter. Fuses are in many ways unsatisfactory; the exact point at which they blow is somewhat indeterminate, and is liable to alter with the life of the fuse. Further, the constant expansion and contraction on heating and cooling is apt to loosen the terminal screws. This difficulty is, of course, obviated when spring contacts are employed.

Fuses are, however, invaluable, in spite of their faults, for the protection of small circuits where the cost of a circuit breaker would be prohibitive. Most wiring rules insist that fuses shall be used on each pole wherever a reduction in the size of conductor takes place, and in each branch when it is tapped off a main circuit. They are generally of such a size as to melt at from 25 per cent to 100 per cent above normal full-load current. A fuse should be mounted in a non-inflammable case (generally either of porcelain or metal) sufficiently open to allow of the escape of heated air and volatilised metal when the fuse blows, without cracking the cover. When dp, there should be a suitable insulating partition between the two poles.

Many varieties of fuse have been brought forward from time to time; in fact it is probable that no class of electrical apparatus has lent itself to greater modification. It will here be possible to refer to only a few

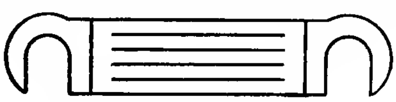


Fig. 1.—Notched-end Fuse

of the main types. In the first place, there is a simple fuse consisting of a wire or strip of metal fixed between two clamping screws, a modification consisting in special notched metal end-pieces to go under the terminals (see fig. 1). This type of fuse is often so proportioned that it is only possible to place the correct size of fuse in the terminals. It may be termed a *notched-end fuse.*

Cut-out Fuse, somewhat similar to the simple fuse, but provided with clip contacts as used for knife-switch contacts. The fuse-wire itself is usually contained in a china tube, which also serves the purpose of a handle for withdrawing the fuse.

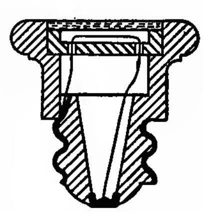


Fig. 2.—Plug Fuse

Plug Fuses.—Fig. 2 is an example of a plug fuse arranged with the fuse-wire visible and stretching between the two metal portions of the plug. With this type also it may be made impossible to place any except the correct size of plug in the screwed socket.

Cartridge Fuses differ from the preceding in that the fuse-wire is carried in a tube

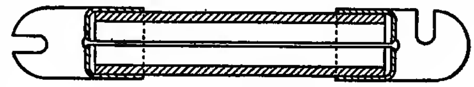


Fig. 3.—Cartridge Fuse

of insulating material which is provided with suitable metal caps to fit into the terminal receptacles of the holder (see fig. 3).

No-arc Fuses are fuses of the cartridge type in which the space surrounding the fuse wire is filled with powdered material which absorbs the volatilised metal produced when the fuse blows, and so quenches the arc consequent on the rupture of the circuit.

Expulsion Fuses are those in which the fuse is placed in an enclosed chamber with a vent-hole, so that on the blowing of the fuse the hot air, with the volatilised metal, is expelled through the vent and the arc is thereby blown out.

Magnetic Blow-out Fuses are those in which the fuse is carried in a chamber subject to the action of a magnetic field produced by the current itself, which tends to blow out the arc formed when the fuse ruptures.

Quick-break Fuses are arranged to break the circuit quickly when fused, this being effected by means of a weight suspended from the centre of the fuse, or by springs attached to the ends of the fuse wire, or by other suitable means.

For continuous circuits of 500 volts and upwards automatic circuit breakers should be used wherever possible, particularly for currents of 100 amp and upwards. For h pr alternating circuits the same remark applies, though in the latter case the automatic circuit breaker generally takes the form of an oil switch arranged to trip automatically. Formerly expulsion fuses and other fuses of special types were employed on such circuits, but the automatically tripped oil-break switch has been found to be most satisfactory in operation, and is now almost universal for h pr work. One disadvantage of the fuse was that the arc set up on breaking caused surges in the line, which, under suitable conditions of capacity, caused disastrous rises of pressure, while with the oil-switch little or no arcing occurs at the final break, and the surging effect is avoided, or at least minimised.

Among the older types of ht fuses may be mentioned the oil-break, in which the fuse broke circuit under oil, or was drawn under oil by a spring immediately after rupture.

Extra h pr transmission lines are in some instances protected by automatic oil-break switches in the stations or substations, but occasionally fuses are used; for instance, on the branch circuits of one of the Niagara lines, operating at 60,000 volts, fuses are used which consist of thin copper wire, 5 m long, covered by small rubber hose, and supported at each end and at the centre by insulators. The three fuses of each three-phase line are about 8 m apart. (See the description of the plant of the Niagara, Lockport, and Ontario Power Company, in Proc. A.I.E.E., Sept., 1907, Mershon.) (Ref. 'Electricity Control', Leonard Andrews, and 'Modern Electric Practice'; Elec., vol. lv, p. 8; vol. lvi, pp. 184, 468, Schwartz and James; Lacount, Proc. A.I.E.E., vol. xxiv, p. 893.) [F. W.]

See also CIRCUIT BREAKER; CIRCUIT BREAKER, THERMAL OVERLOAD TYPE; CIRCUIT-OPENING DEVICES; SWITCH; FUSE WIRE.

Fuse, Supply. See SUPPLY MAIN.

Fuse Board, a panel with fuses mounted upon it. Such a board is frequently used at a point in a circuit where several branch circuits leave it. On one half of the board are fixed the fuses in the positive mains, and on the other half the fuses in the negative mains, with an insulating partition between the two poles. The panel is generally of enamelled slate or marble, and is often enclosed in a box with a glass door fitted with a lock. See BOX, DISTRIBUTING.

Fuse Box, a case of metal, stoneware, or other suitable material, containing terminals, with a fuse or fuses connected between them.

Fuse Panel, a panel of marble, enamelled-slate, wood, &c., upon which one or more fuses are mounted. Fuse panels are most frequently met with in lighting installations in buildings, and as a rule a number of fuses are grouped together on a single panel which is placed at the point where the main is subdivided into several minor circuits. The panel is often enclosed in a case with a glazed door fastened by a lock. See BOX, DISTRIBUTING.

Fuse Wire.—Almost any wire may be used for a fuse wire, but the most generally satisfactory seems to be copper. The fusing current of a wire depends not only on the metal of which it is composed, but also on its surroundings, the state of its surface, and other factors. Some metals, such as aluminium, become coated with oxide or sulphide, which acts as a tube, holding the molten metal inside and tending to prevent rupture. To obviate this, fuses have been made with a blob of metal hanging in the middle, whose weight will cause breaking. Common *fuse wire* is either lead or an alloy of lead and tin. Zinc is used for enclosed fuses, but copper fuses are coming more and more into favour. The chief disadvantage of copper is the high temperature to which it must rise before fusing. See also FUSE. (Ref. Elec., vol. lv, p. 8, vol. lvi, pp. 184, 464, Schwartz and James; Lacount, Proc. A.I.E.E., vol. xxiv, p. 893.)

Fusel Oil. See 'Amyl Alcohol' under ALCOHOLS.

Fuses, Rating of. See FUSE.

Fusible Plug. See FUSE.

Fusing Current, that amount of current which will generate sufficient heat to melt the conductor in which it is flowing. See Table in article on FUSE (p. 228).

Fusing Point, the temperature at which any metal or other substance will melt.

G

G, the preferable abbreviation for gram (which see).

Gal, the preferable abbreviation for gallon. 1 gal is equal to 4·53 liters, *i.e.* to 4·53 cu dm. Consequently 1 gal of water weighs 4·53 kg or 10 lb (avoirdupois). 1 metric ton of water has a volume of 220 gal.

Gallery, a device for securing shades or globes to electric-light fittings, such as holders, brackets, &c. A gallery is usually made of brass, and may be provided with three set-screws for holding the shade, and with some arrangement for securing the gallery to the fitting.

Galvanic Action, Volta's Law of. See Law of Volta.

Galvanic Battery. See Battery, Primary.

Galvanic Polarisation. See Polarisation, Electrolytic, in Battery; Battery, Primary.

Galvanit, the commercial name given to a series of powders which can be used for electroplating metals without the use of external current. To electroplate with these powders it is only necessary to slightly moisten the surface to be plated and to rub the dry powder on with a rag or brush.

The process is said to depend upon the reaction which ensues between one ingredient (the electropositive metal) and the other ingredient (the metallic salt) on the addition of moisture to the mixture. In this reaction the electropositive metal constitutes the anode, and the object treated constitutes the cathode. The finely-powdered electropositive metal in the mixture makes innumerable contacts with the cathode surface, and acts as many minute anodes. These set up circulating currents which throw down a metallic deposit on the cathode.

The deposit obtained is said to be equally as good as that obtained in the ordinary process of electroplating, and it is stated that practically all metals which can be electrodeposited in the ordinary manner can be deposited by means of these powders.

Galvano Metal Paper Brush. See 'Endruweit Brush' under Brushes.

Galvanometer, a term nowadays usually applied to instruments for measuring very small quantities of electricity, but in earlier days sometimes also applied to instruments for measuring heavy currents. Nearly all galvanometers depend on electromagnetic principles.

The *sensitiveness of a galvanometer* is measured by the reciprocal of its constant (see Galvanometer Constant). A sensitive galvanometer is one requiring a very small current or potential to occasion a stated deflection. It does not follow that a galvanometer which is sensitive for current measurement will also be sensitive for potential measurement.

Shunted Galvanometer.—The sensitiveness of a galvanometer used for measuring current may be reduced to any desired extent by connecting a resistance of known value in parallel with it. This resistance is then spoken of as the shunt to the galvanometer. See also Shunt Box.

Galvanometer as Amperemeter.—For use as an amperemeter the galvanometer may be shunted by a suitable low resistance.

Galvanometer as Voltmeter.—Any galvanometer may be used as a voltmeter by putting in series with it sufficient resistance to allow the correct current to pass for a given reading at the measured pressure. Thus a galvanometer taking m micro-amperes per division would require a resistance $\frac{v \times 10^6}{m \times 8}$ to read v volts for a deflection of 8 divisions.

Potential Galvanometer.—A galvanometer arranged with a high resistance in series, or having a high internal resistance, may be made to measure potential if its current-constant and its resistance are known. See also Galvanometer as Volt and Amperemeter above.

Astatic Galvanometer, an instrument whose action depends on the torque produced on a suspended astatic magnetic system by the current circulating in the system of fixed coils. The control is by a permanent magnet or by magnets so arranged as to affect one part of the suspended magnetic system only. See Astatic Needle.

Ballistic Galvanometer, an apparatus for measuring the impulse due to a transient current. Specially suited for measuring any change in the flux passing through a secondary winding or test-coil connected to the galvanometer. The throw is proportional to the quantity, $\int i\,dt$, which, with a constant secondary resistance is proportional to $\int e\,dt$; where i and e are instantaneous values of induced currents and pressures respectively. The instrument is therefore a coulomb-meter. Since the induced pressure is proportional to the rate of change of flux, the impulse is proportional to the total change of flux. This impulse is proportional to the sine of half the angle of throw. If a reflecting method be used, and a straight scale, the observed deflection or throw depends upon the tangent of twice the angle of movement of the needle. For small deflections, however, the change of flux can be taken as directly proportional to the observed deflection.

To *standardise* a ballistic galvanometer, it is best to obtain a deflection due to a known change of magnetic linkage, as that occurring in the secondary of an air-core ring-magnet of known dimensions. The advantage of using this method is that the secondary of this standardising ring may be left in circuit throughout the entire test, and no change of resistance, and therefore no change of unknown damping constants, arises between the test and the standardisation. The discharge from a known condenser charged to a known pressure through the galvanometer is, however, sometimes used for standardising purposes.

In order that the scale may be evenly divided, the controlling force must be proportional to the deflection. The reading of the first swing or *kick* is proportional to the quantity passed through the galvanometer if the time period of the instrument is large compared with the time of passage of the discharge, and if there is no damping present.

DAMPED GALVANOMETER.—This is the exact opposite of a ballistic galvanometer, and is one in which means are provided to check the free swing. There are three methods employed:—

1. For moving-coil instruments, by winding the coil on a copper or aluminium former in which eddy currents are induced by the motion of the coil in the magnetic field. These eddy currents dissipate energy, and therefore tend to bring the movement to rest.

2. By fitting the movement with a mica vane, or with vanes, to increase the air friction.

3. By allowing a part or the whole of the movement to work in oil or glycerine.

See DAMPING; DAMPED; DEAD-BEAT OR APERIODIC ELECTRICAL MEASURING INSTRUMENTS.

APERIODIC GALVANOMETER.—This term is applied to a galvanometer when the damping is just sufficient to stop the movement from swinging beyond its reading, but not sufficient to render it sluggish. This instrument will then accurately follow the variation of current in any circuit whose time period is greater than that of the free swing of the instrument if undamped.

DIFFERENTIAL GALVANOMETER, a galvanometer having two windings so arranged as to produce opposite effects on the movement. Generally used as a zero instrument, the galvanometer indicates a definite relation between the magnitudes of the currents in two circuits.

EINTHOVEN'S GALVANOMETER, employs a single fine wire in a very strong magnetic field. The wire carries the current to be measured, and its motion across the field is observed by a microscope or other optical method. It is extremely sensitive and very rapid in action. A galvanometer of this type is used in conjunction with a photographic recorder as a high-speed receiver in wireless telegraphy (Poulsen system).

DIRECT-READING GALVANOMETER.—A galvanometer is termed *direct-reading* when its constant is unity. Its indications are thus simply proportional to the quantity measured.

MOVING-COIL GALVANOMETER.—This is a class of galvanometer in which the deflection is produced by the effect of current flowing in a movable coil suspended or pivoted between the poles of a permanent magnet.

The AYRTON-MATHER GALVANOMETER belongs to this class. In this galvanometer, shown diagrammatically at fig. 1, the two sides of the coil are wound quite close together without any intervening iron. For ballistic work the coil is mounted in an ivory cylinder, while for a damped instrument a silver cylinder is used. The suspension is by means of a strip of very thin phosphor bronze.

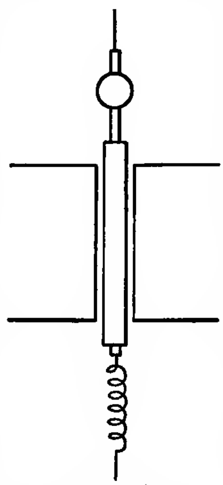


Fig. 1.—Ayrton-Mather Galvanometer

The D'ARSONVAL GALVANOMETER is also of the moving-coil class. It has, however, a fixed cylindrical soft-iron core within the moving coil, and the control is usually by torsion on the phosphor-bronze suspension. It has the advantage of being practically free from errors due to stray magnetic fields.

MARINE GALVANOMETER.—For use on ships it is essential that the movement of a galvanometer shall not be affected by changes of level due to rolling. To achieve this end a D'Arsonval-type moving-coil galvanometer is usually employed with a suspension composed of a single wire or strip of phosphor-bronze pulled tight from above and below by flat springs.

THERMO-GALVANOMETER.—The current flows through a very fine short wire of high resistance, termed the *heater*. This wire is shown at H in fig. 2. Over the heater is suspended vertically a thermo-couple T J, to which a mirror M is attached. The couple forms a closed circuit, and hangs in a powerful magnetic field, N S. In action, the current raises the temperature of the heater and warms the lower junction, thus causing a current in the couple circuit, which, reacting on the magnetic field, causes the couple to turn, thus indicating the current in the main circuit. The instrument is very sensitive, and is particularly suitable for measurements of small hf currents in wireless telegraphy. The thermo-junction T J is incorporated with the coil at its lower end. The current to be measured is passed through the heater H, which consists of a fine platinum or platinised-quartz fibre placed just below the thermo-junction. By this means, a current is produced in the moving coil, depending on the temperature of the *heater*, and therefore on the mean square of the current passing through it. The suspension and control are by a quartz fibre. Very little power is required to actuate this instrument, which is equally correct on continuous or alternating circuits. The arrangement is the invention of Duddell.

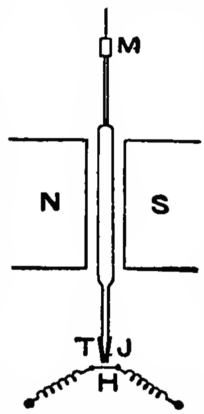


Fig. 2.—Thermo-Galvanometer

MOVING-MAGNET GALVANOMETER. — In this class of galvanometer the deflection is produced by the effect of current flowing in a fixed coil around a movable magnetic needle usually suspended by a silk or quartz fibre.

DETECTOR GALVANOMETER. — This is a strongly-made portable galvanometer of the moving-magnet class, usually consisting of a fixed coil and a pivoted magnet. It is used chiefly in tracing out circuits, and also in testing circuits for continuity.

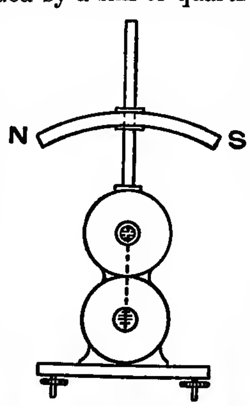


Fig. 3.—Thomson Mirror Galvanometer

THOMSON MIRROR GALVANOMETER. — This instrument is of the astatic, moving-magnet class. There are four separate coils, placed one in front of and one behind each of the two magnetic needles. Above the whole instrument is the control-magnet N S, mounted on a vertical brass rod, and capable of being adjusted either with reference to height or to the magnetic meridian. Various arrangements of the coils, in series or parallel, may be obtained, and the sensitiveness may also be adjusted by the control-magnet. The moving system comprises a mirror which reflects a beam of light. The instrument, which is illustrated in fig. 3, is thus a type of reflecting galvanometer (which see below).

TANGENT GALVANOMETER, a galvanometer comprising a magnet of very small length suspended at the centre of a coil of large diameter and small section. If the instrument is so set that when there is no current in the coil, the suspended magnet lies in the plane of the coil, *i.e.* if the plane of the coil is set in the magnetic meridian, then the current passing through the coil is proportional to the tangent of the angle by which the magnet is deflected from the plane of the coil, *i.e.* from its zero position.

ABSOLUTE GALVANOMETER. — When the dimensions of the coil of a tangent galvanometer are accurately known, the field at the centre may be calculated. Hence, if care is taken that the field produced is uniform, the current may be directly calculated from the deflection. Helmholtz's form (see next paragraph) is most suitable for this purpose, but since the method is dependent on the strength of the controlling field, it is not truly absolute. The Kelvin balance should be used for this purpose. See KELVIN BALANCE.

HELMHOLTZ GALVANOMETER.—In order to obtain a more uniform field at the centre of a tangent galvanometer coil, Helmholtz replaced the single coil by two similar coils situated on a common axis, and lying in parallel planes at a distance apart equal to half their common radius, with the magnetic needle suspended at the centre.

SINE GALVANOMETER. — This galvanometer is similar in construction to the tangent galvanometer, except that the needle is brought to zero by rotating the coil through a measured angle. The current passing is proportional to the sine of the angle through which it is required to move the coil in order to bring the needle to zero.

REFLECTING GALVANOMETER.—In place of a pointer attached to the moving part of a galvanometer, a slightly concave mirror may be used. If a beam of light fall on the mirror from a fixed point, and if it is then reflected on to a scale at some distance, a very sensitive measurement of any deflection will be given by the movement of the spot of light over the scale. A common form of the instrument employed for rough testing is illustrated in fig. 4. The Thomson galvanometer, already described, and illustrated

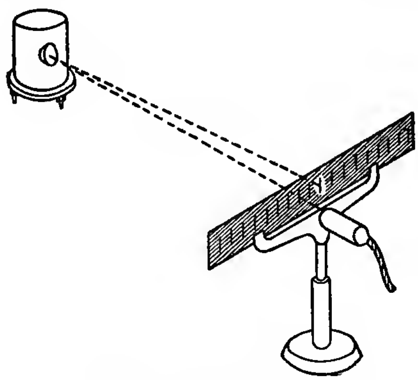


Fig. 4.—Reflecting Galvanometer

in fig. 3, is an exceedingly sensitive type of reflecting galvanometer.

GALVANOMETER MIRROR.—The mirror used on a reflecting galvanometer is usually of silvered glass, and about 1 cm in diameter, with a curvature corresponding to a focal length of 1 m.

TWISTED-STRIP GALVANOMETER, a development of an early type devised by Ayrton and Perry, and known as a *twisted-strip ammeter*. The present instrument was devised by Duddell. A fine strip of phosphor-bronze is twisted in both directions from its centre, where it carries a small mirror. It is supported vertically in a frame arranged to compensate for atmospheric temperature alterations. The deflection is simply produced by the heating effect of the current, which occasions a tendency to twist or untwist the strip, and so to rotate the mirror.

SHIELDED GALVANOMETER.—A galvanometer may be shielded from external magnetic influences by surrounding it with a wrought-iron case. For protection from electrostatic fields it is only necessary that the galvanometer should be surrounded by metal, or by a network of conductors. Electrometers are usually shielded in this way.

TORSION GALVANOMETER, a galvanometer in which the needle is brought back to zero by rotating a torsion head. If the instrument is of the moving-magnet type, the reading will, over a wide range, be directly proportional to the current. (Ref. 'Electrical Engineering Measuring Instruments', Parr; 'Industrial Electrical Measuring Instruments', Edgcumbe; 'Handbook of Electrical Testing', Kemp.) [L. M.]

Galvanometer Constant, the number by which a galvanometer reading must be multiplied in order to obtain the quantity to be read. If the galvanometer readings are not directly proportional to the quantity to be measured, the law of the instrument must first be considered. Thus in a tangent galvanometer

$$C = K \tan \theta,$$

where C is the current, θ the deflection, and K the *constant.*

Galvanometer Mirror. See GALVANOMETER.

Galvanoscope, a term used to denote an instrument (usually electromagnetic) which is not suitable for quantitative measurements, but is employed for *indicating* the presence of a current, and possibly its direction. The instrument is now little used, since measuring instruments (ammeters and galvanometers) are usually much more suitable. See DETECTOR, MAGNETIC; ELECTROLYTIC DETECTOR.

Gap Diameter, the diameter of a dynamo-electric machine measured at the air gap. See AIR GAP; AIR-GAP DIAMETER.

Gap Field, the magnetic field in the air gap of a dynamo or motor.

Gap Reluctance, the ratio of the line-integral of the magnetising force on the air gap to the total number of magnetic lines passing across the air gap. The gap reluctance is proportional to $\frac{H \times l}{M}$ where H is the magnetising force, l the length of magnetic path in the air gap, and M the total number of magnetic lines. If the magnetic lines are uniformly distributed over the pole surface and pass radially into the armature, then $\frac{M}{H}$ is equal to A, the pole-shoe area, and l is equal to the radial depth of the air gap, and therefore the gap reluctance is proportional to $\frac{l}{A}$. Since in practice the distribution of the lines is not so simple, corrections have to be made, and the reluctance will be proportional to $\frac{l^1}{A^1}$ where l^1 is a corrected length, and A^1 a corrected area. The imaginary air gap having the area A^1 and the length l^1 is called the *equivalent air gap.*

The lines of magnetic force spread out from the edges of the pole fields into the interpolar space, forming a magnetic fringe at the edge of the pole piece; this is known as the *fringing* or *spreading* of the magnetic field. This phenomenon has the effect of increasing the effective area of the air gap, and the coefficient by which the pole-shoe area A must be multiplied to give the effective area A^1 is called the *spreading coefficient* or *fringing coefficient.*

When slotted armatures are used, the lines of force crowd into the teeth, avoiding the polar region above the slots. This increases the reluctance of the air gap, and is conveniently allowed for by multiplying the radial length of the air gap l by a correction coefficient giving l^1, the effective length. The crowding of the lines into the top of the teeth is sometimes referred to as the bunching of the magnetic field, and the correction coefficient *k*, where $k\,l = l^1$, is then called the *bunching coefficient.* Many different methods of calculating the spreading coefficient and the bunching coefficient have been proposed. (Ref. Hele-Shaw, Hay and Powell, Journ.I.E.E., vol. xxxiv, p. 21.) [W. B. H.]

Gap-to-slot Ratio, the ratio of the length of the gap to the width of the slot opening. This ratio serves as a gauge of the amount of flux tufting which will occur. See TUFTING OF FLUX.

Garton Lightning Arrester. See LIGHTNING ARRESTER.

Gas, Compressed, as an Insulator. See COMPRESSED GAS AS AN INSULATOR.

Gas, Electrolytic, the gas given off by the decomposition of an electrolyte. See ELECTROLYSIS.

Gas Battery. See BATTERY, PRIMARY.

Gas-electric Generating Set, an electric generator driven by a gas engine.

Gases, Dielectric Strength of. See DIELECTRIC STRENGTH; COMPRESSED GAS AS AN INSULATOR.

Gas-power for Driving an Electricity Generating Station. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Gas Voltameter. See VOLTAMETER.

Gassing, a condition usually observed at the end of the charge of a battery, due to the presence of minute gas bubbles given off by the plates. They may be sufficient to give the electrolyte a milky appearance. See ACCUMULATOR; ACCUMULATOR PLATES.

Gauge.—

['*Gauge,* (*a*) a general term applied to various kinds of measuring instruments and to linear measurements. (*b*) The thickness of a plate or the diameter of a wire on the in, mm, or on any arbitrary scale. (*c*) The distance between the rails of a railway or of a tramway. In the case of a railway it is the distance between the inner sides of the heads of the rails. In the case of a tramway it is the distance between the inside edges of the tread of the rails, *i.e.* over and including the grooves.'—I.E.C.]

Gauge, Ampere. See AMMETER.

Gauss, a name given to the absolute electromagnetic unit of magnetic induction in the cgs system, *i.e.* the flux density in lines per sq cm. Gauss was a great mathematical electrician of the last century. His greatest work consisted in an analysis of terrestrial magnetism. His name is associated with his theorem on the distribution of force, which states that the integral of the normal force over a closed surface is 4π times the charge within the surface. This gives the relation between unit charge and unit tube or line of force. See FIELD, MAGNETIC; LINE OF INDUCTION.

Gauze Brushes. See BRUSHES.

G.B. Surface-contact System. See SURFACE-CONTACT SYSTEM.

G deg cal, the preferable abbreviation for gram-degree-calorie. The g deg cal is the energy absorbed by 1 g of water when its temperature is increased by 1° C. 1 kelvin (1 kw hr) is equal to 860,000 g deg cal.

Gear, Cable-charging. See CABLE-CHARGING GEAR.

Geared Motor, an electric motor which drives the axle of a vehicle or the shaft of a machine through the intermediary of gearing, such, for instance, as toothed wheels. See GEARING FOR ELECTRIC MOTORS; MOTOR, BACK-GEARED.

Geared Railway Motor. See GEARED MOTOR.

Gearing, Magnetic. See MAGNETIC GEARING.

Gearing for Electric Motors.—The speed of an electric motor is in most cases greater than that of the machine which it is required to drive, so that some form of speed-reduction gearing becomes necessary.

Belt Gearing.—Where space permits, belt gearing gives very satisfactory results. In fig. 1 A is the pulley of the motor and B the pulley on the driven shaft. The speeds of the motor and driven shaft are inversely proportional to the diameters of their respective pulleys. The belt C should be just sufficiently tight to transmit the required

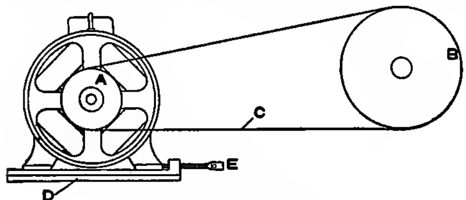


Fig. 1.—Belt Gearing

power. The motor stands on the under-bed D, and can be moved by the screws E, so that the stretch of the belt can be taken up without requiring to cut and rejoint it. For ordinary indoor work, leather belting gives good results. For ordinary powers and speeds, up to, say, 25 hp, single leather belting with cemented joints made up endless at the belting factory is very satisfactory. The length should be such that, when new, the motor requires to be close up to the nuts through which the screws E work; then as the belt stretches, the motor is moved farther along.

Link Belting.—For higher powers, double leather belting may be used, or link belting, which consists of a series of leather links held together by steel rivets. Being flexible, link belting bends readily round the pulleys, and, being heavy, it grips the pulleys without requiring to be stretched as tight as ordinary belting, while, also on account of its weight, it runs steadily and with freedom from slapping.

For outdoor work in the rain, or in buildings where the atmosphere is moist, *canvas belts* impregnated with india-rubber are preferable to leather. It is very important that they should be made up endless in the factory to the right length, as they cannot be jointed satisfactorily. The required degree of tightness of the belt depends on the coefficient of friction between the belt and the pulley, and on the arc of the pulley embraced by the belt becoming greater as these decrease.

Jockey Pulley.—Where there is considerable difference in the sizes of the pulleys, the arc embraced by the belt on the smaller pulley is apt to be so small that the belt has to be stretched very tight to transmit the power. In such a case a jockey pulley may be used with advantage (see fig. 2). This consists of the small pulley, shown at A, run-

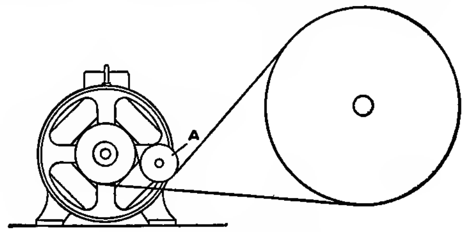


Fig. 2.—Jockey Pulley

ning free on a stud. The slack side of the belt is led round this pulley. By this means the arc of embrace is increased, and the same power can be transmitted with less tension on the belt. The arrangement was introduced by Messrs. Mather & Platt for electric driving about the year 1884.

Spur Gearing.—Where space is limited, or where it is necessary that the motor and

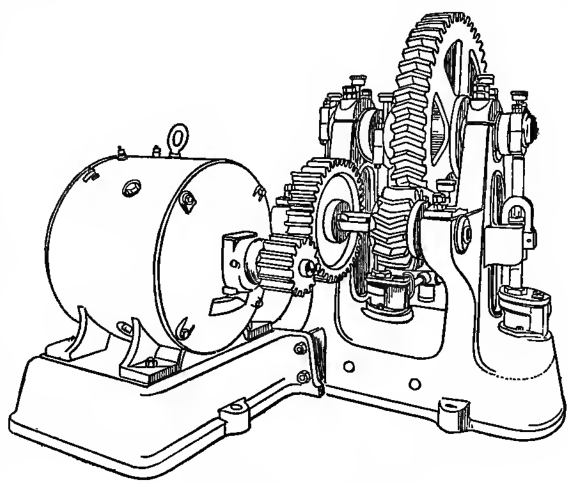


Fig. 3.—Motor with Spur Gearing

its machine should be self-contained on one bedplate, spur gearing (see fig. 3) is used. In this class of gearing each wheel has projecting teeth which fit into recesses on the opposing wheel, so that the motion is transmitted without slip. An essential point in spur gearing is that the shape of the teeth shall be such that the motion of the driven wheel is absolutely uniform with that of the driver.

In fig. 4 a 24-tooth wheel is driving one having 49 teeth, a ratio of 2·05. The ratio between the wheels should always contain some odd fraction, so that the same pair of teeth will only come together at long intervals, so regularising the wear and lengthening the life of the gear. The line A B, called the *line of contact*, is tangential to the two circles C, D, which are the base circles from which the involute-shaped curves, which

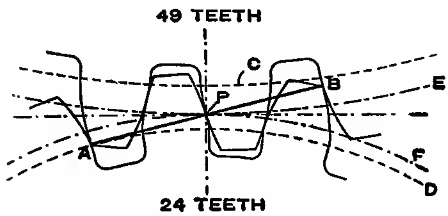


Fig. 4.—Toothed Gear

form the working portions of the teeth, are struck. As the wheels revolve, the point of contact of the teeth travels along the line A B, which at any point is normal to their surfaces. Thus in any position of the teeth between the points A and B the line which is normal to their surfaces passes through the point P, known as the *pitch point*, and the relative angular velocities of the wheels are the same as though they were plain cylinders coinciding with the circles E, F, rolling upon each other without slipping. The circles E, F are struck through the pitch point, and are called the *pitch circles*. During the movement from A to B the teeth slide upon each other, so giving rise to frictional losses. These losses are a maximum at the points A and B, where the speed of sliding is greatest, and zero at P, since at this point there is no sliding. Thus the efficiency of a pair of teeth is not a constant quantity, but is lowest at A and B, and 100 per cent at P. The efficiency during the movement from A to P is a trifle lower than from P to B, the difference being, however, too trifling to be of any practical importance. See LOSS, GEARING.

HELICAL GEAR.—If the teeth are placed at an angle on the rim of the wheel, thus forming a portion of a spiral, they are known as *helical teeth*, and they work together with great smoothness. In order to avoid end-thrust, two sets of teeth having opposite inclinations are cut on the same wheel.

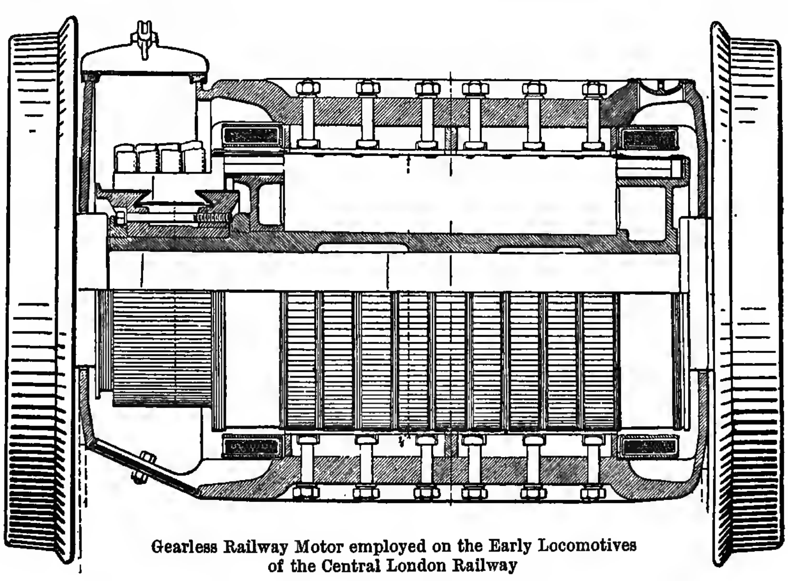
WORM GEAR.—Where entire freedom from noise is required, worm gearing is used (see Plate facing p. 58). This comprises a worm with spiral threads turned upon it, which mesh with the teeth of a worm wheel. These teeth are cut with an angle corresponding to that of the worm threads. When the worm is revolved it draws the wheel round. Owing to the revolution of the worm there is a greater amount of sliding between the teeth of worm gear than of spur gear, and its efficiency is consequently lower.

FRICTION GEAR.—In some instances, in order to avoid noise, teeth are dispensed with, and the wheels are plain cylinders pressed together by a spring or weight, transmitting the motion by their frictional grip. In order to increase the friction it is usual to make one wheel of the pair of wood, or of compressed paper or leather. Such gear is not used to any great extent. (Ref. 'Machine Design', Unwin; 'Mechanism of Machinery', Kennedy.) See MAGNETIC GEARING; MOTOR, BACK-GEARED.

[C. W. H.]

Gearing Losses. See LOSS, GEARING; GEARING FOR ELECTRIC MOTORS.

Gearless Motor, an electric motor (especially a railway motor) which is coupled



Gearless Railway Motor employed on the Early Locomotives of the Central London Railway directly to the wheel, axle, or machine which it drives (its axis being co-linear or concentric with that of the driven shaft), without the intervention of gearing. A gearless railway motor is illustrated in the fig. See MOTOR.

Geissler Tube, a glass tube containing a partial vacuum, *i.e.* a gas at very l pr and density, and provided with two metal electrodes between which a current may be made to flow by connecting one to the positive and the other to the negative terminal of a source of current. As the density of air in the bulb is gradually reduced by pumping some out, the character of the discharge (the current in the gas) gradually changes from a thin spark to a broad ribbon, which finally fills the whole bulb except a space in the neighbourhood of the negative electrode. A large number of distinct stages are easily recognisable, each corresponding to a definite pressure and density of the contained gas. See CROOKES' TUBE; VACUUM TUBE; HITTORF'S TUBE.

Gem Lamp. See LAMP, INCANDESCENT ELECTRIC.

Generating Plant.—The term *generating plant* is applied to the whole of the machinery and apparatus which has to be installed for the purpose of generating electricity for any given purpose. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Generating Station.—

['*Generating Station.*—The expression includes any station for generating, transforming, converting, or distributing electricity.'—Electric Lighting Act, 1909, Clause 25.]

Electricity supply station is a more suitable term. See also CENTRAL STATION FOR THE GENERATION OF ELECTRICITY; ELECTRICITY SUPPLY STATION.

Generating System.—There are several systems by which electricity is generated for purposes of public supply. The most important are as follows:—

CONTINUOUS-CURRENT, CONSTANT-POTENTIAL.—In the continuous-current (cc) constant-potential system, the pressure at the terminals of the generators is maintained constant. Every lamp, motor, &c., is on a separate circuit, and the amount of current varies as more or less of these are brought into use.

CONTINUOUS-CURRENT, CONSTANT-CURRENT.—In the cc constant-current system which has been developed by Thury (see Highfield's paper, Journ.I.E.E., vol. xxxviii, p. 471), all apparatus in the circuit is connected in series, and the value of the current is maintained constant, the pressure at the generators being varied to suit the quantity of apparatus in the circuit at any given time.

ALTERNATING-CURRENT, SINGLE-PHASE.—In the alternating-current (ac) single-phase system, a sp ac of high potential is generated at the station, and is led to transformers placed in substations where the pressure is reduced to one suitable for distribution to consumers.

ALTERNATING-CURRENT, TWO-PHASE.—In the ac two-phase system, two sp currents are sent out from the central station. The generators are so designed that one of the currents is at its crest value when the other is at zero, so that there is, so to speak, no dead centre, and this system is far better suited for motors than is the sp system.

ALTERNATING-CURRENT, THREE-PHASE.—The ac three-phase system is a further development in which the generators are designed to send out three sp currents, so placed that when any one is at zero the other two are each at 86 per cent of their crest value, and when any one of them is at its crest value, each of the other two is at 50 per cent of its crest value. This is the system most commonly employed, as it requires the least quantity of copper in the mains for the transmission of a given quantity of energy at a given pressure between lines.

TRACTION SYSTEM.—At present the most commonly used system for traction is a combination of the ac three-phase and the cc constant-potential systems. Ac three-phase electricity of h pr is generated, and is led to substations where it is converted to cc electricity at a pressure usually of 500 to 750 volts, which operates the motors on the cars or locomotives. This system is employed on most of the tramways and electric railways at present at work in Britain. The ac sp system is now coming into limited use for traction, series-wound sp motors being used on the cars, so that no conversion to cc is required. This system is now in operation on the London, Brighton, and South Coast Railway for the service between London Bridge and Victoria, and it is also used for propelling trains on the Heysham section of the Midland Railway.

See also CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Generator, a dynamo-electric machine by means of which mechanical energy derived from an external source is converted into electric energy. See DYNAMO-ELECTRIC MACHINE.

[By § 7 of the 1907 Standardisation Rules of the A.I.E.E. a *generator* is defined as a machine which 'transforms mechanical power into electrical power'.]

['Any machine capable of transforming mechanical into electrical energy, *e.g.* a *dynamo* or *alternator*.'—I.E.C.]

Generators are of two main classes: (1) Continuous-current generators, or, preferably, *continuous generators*. (2) Alternating-current generators, which are usually termed briefly *alternators*.

CONTINUOUS GENERATORS

A continuous generator consists of two chief parts, one of which is fixed while the other moves. The fixed part is called the *field-magnet*, and the moving part the *armature*. The armature is provided with a commutator to rectify the direction of the current generated (except in the case of homopolar generators, which are defined in this article).

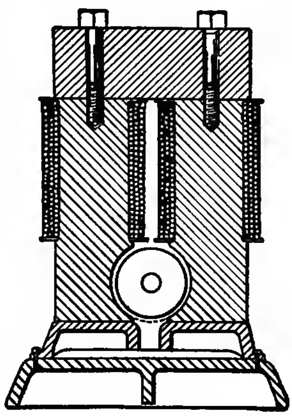


Fig. 1.—Under-type Bipolar cc Generator

Continuous generators may have field-magnets with two, four, or more poles. If the field-magnets have but two poles, the machine is termed a *bipolar generator*. Most of the earliest generators were of the bipolar type. This type may, in turn, be sub-classified into the *under-type* and the *over-type*. Illustrations of these two types are given in figs. 1 and 2.

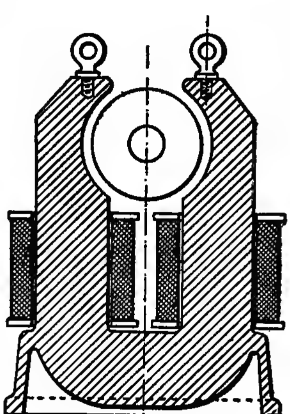


Fig. 2.—Over-type Bipolar cc Generator

EDISON DYNAMO.—The original Edison dynamo was an *under-type* machine, but with much longer magnet limbs than are shown in the design in fig. 1. In some of the very earliest of Edison's designs, several magnet limbs were arranged in parallel with one another. At that time there was no correct understanding of the principles of the magnetic circuit.

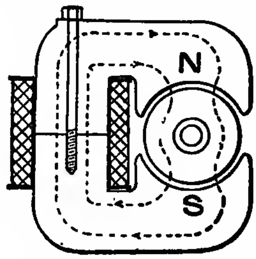


Fig. 3.—'C' Type cc Generator

EDISON-HOPKINSON DYNAMO.—Dr. Hopkinson, with his correct understanding of the principles of the magnetic circuit, re-designed the Edison type of dynamo, shortening the magnetic circuit, and introducing more rational proportions at all parts of the design. The designs already indicated in figs. 1 and 2 have the more correct proportions first adopted by Hopkinson and by Kapp.

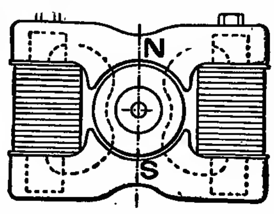


Fig. 4.—Consequent-pole Bipolar cc Generator with Two Field Spools

Fig. 3 gives an outline of the magnetic circuit of a *C-shaped single-horseshoe* type of bipolar generator, and in fig. 4 a *double-horseshoe* type is illustrated. This latter is also of Hopkinson's design, and was widely known as the *Manchester* type. It will be seen that consequent poles (see POLE, CONSEQUENT) are employed instead of

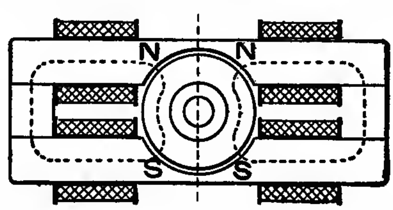


Fig. 5.—Consequent-pole Bipolar cc Generator with Four Field Spools

the salient poles which characterised the previous design. Consequent poles also characterise the bipolar design shown in fig. 5, but in this case there are four field coils whereas only two were required in figs. 1, 2, and 4, and only one in fig. 3. Another variety of bipolar design, to which the term *ironclad* was formerly sometimes given, is shown in fig. 6. Such early designs were, however, generally open at the sides, whereas a modern ironclad generator (more usually termed a *totally enclosed generator*) is characterised by such a construction that the armature and commutator, and the field-magnet poles and coils, are wholly, or almost wholly, enclosed in an iron or steel casing, which usually forms part of the magnetic circuit.

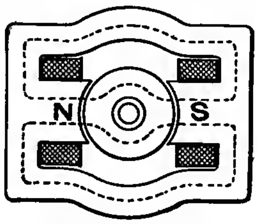


Fig. 6.—Ironclad Salient-pole Bipolar cc Generator

In modern times cc bipolar designs are rarely employed except in the case of machines for very small outputs, or else for such very high speeds as are reached when the generator is directly connected to a steam turbine. Even for steam-turbine-driven cc generators so few as two poles are only rarely employed. When a machine has more than two poles, it is termed a *multipolar generator.*

A six-pole cc generator is shown in end and sectional elevation in fig. 7. This design is fairly typical of approved modern construction. It is for a 1000-rpm, 1000-volt, 1000-kw, six-pole machine. The cast-steel ring A is termed the *yoke.* The salient members B and C are the main poles and the interpoles respectively. The poles (also termed *magnet cores*) terminate in pole shoes D. Each pole carries a coil or coils of copper wire, as shown at E, F, and G. Current passing through these coils provides the required magnetic flux (see FLUX, MAGNETIC). An armature H, comprising a ring of laminated steel plates and carrying copper conductors in slots at its surface, is revolved within the cylindrical space formed by the pole shoes D, the energy being transmitted to the armature through the shaft I. The copper conductors carried by the armature are so interconnected as to constitute an armature winding (see WINDINGS, ARMATURE) from which electricity is delivered to J, the commutator (which see), through *commutator connections* K (see COMMUTATOR, LUG OF). Stationary brushes (see BRUSHES) not shown in fig. 7 rest on the

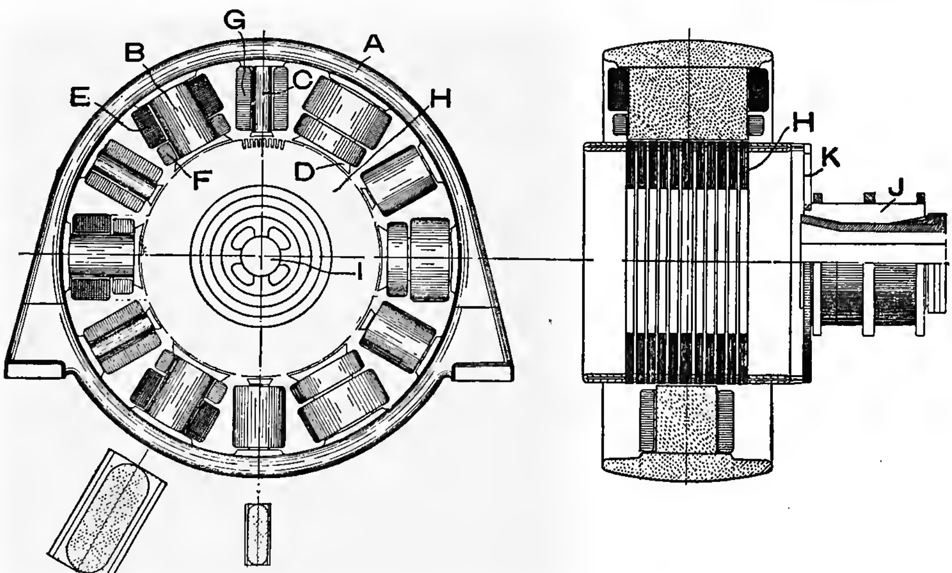


Fig. 7.—Typical cc Multipolar Generator

commutator at suitable points, and afford connections from which the electricity is conducted away to the external circuits where it is required.

It will be observed that the interpoles C are much smaller than the main poles B. The former are auxiliary devices employed for the purpose of securing the sparkless collection of the current from the commutator (see INTERPOLES), and the latter, the *main poles*, are the essential parts of the magnetic circuit which carries the main magnetic flux.

Most modern continuous generators are of the general construction above indicated.

Internal-pole continuous generators have, however, been occasionally employed. In such machines the stationary field-magnet poles are surrounded by a revolving armature. The latter, in such a case, is usually (though not necessarily) of the ring type, carried by a spider at one end, and the conductors on the outer surface of the ring have been utilised as commutator bars, to which brushes are applied. This type of machine is not now made for generating continuous electricity.

The field windings of continuous generators may be supplied with current from some external source, such as an accumulator (which see), or from another generator. In this latter case they are called *separately excited generators.* The excitation may also be supplied from the machine itself. In this case the machine is called a *self-excited generator.* This latter method is by far the most usual with *cc generators. Self-excited generators* may be either (1) Shunt-wound, in which case they are also termed *shunt-excited*; (2) Series-wound, in which case they are also termed *series-excited*; or (3) Compound-wound, in which case they are also termed *compound-excited.* See EXCITATION; COMPOUND-WOUND DYNAMO; COMPOUNDING, AUTOMATIC; COMPOUND-WOUND.

SHUNT-WOUND GENERATOR (or SHUNT GENERATOR), a continuous generator of which the field-magnets are excited by a very small portion only of the current generated in the armature, the exciting current being taken through the field-magnet winding without passing through the external circuit, and being to a great extent independent of the resistance of the latter. The proportion of the total current generated which is thus used for the purpose of excitation varies from 0·3 per cent in large dynamos to 5 per cent or more in small ones.

SERIES-WOUND GENERATOR (or SERIES GENERATOR), a continuous generator in which the whole of the current generated in the armature passes through the windings of the field-magnets, in order to excite the latter, as well as through the external circuit. Thus the excitation of the field-magnets depends upon the resistance of the external circuit.

COMPOUND-WOUND GENERATOR (or COMPOUND GENERATOR), a continuous generator in which part of the excitation is provided by a shunt winding and part by a series winding, usually for the purpose of obtaining automatically a constant terminal pressure or else a pressure increasing slightly as the load increases. The generator illustrated in fig. 7 is compound-wound. E are the shunt, and F the series coils. The interpole coils G are series-wound. See also CONTINUOUS-CURRENT GENERATOR CHARACTERISTICS; COMPOUND-WOUND; EXCITATION; COMPOUND-WOUND DYNAMO; COMPOUNDING, AUTOMATIC.

ALTERNATING GENERATORS

Alternating generators are usually termed briefly *alternators,* whether for generating single or polyphase (which see) electricity. They are built in much more varied forms than are continuous generators. These various types are described in the article ALTERNATOR (which see). The terms *bipolar* and *multipolar* are rarely employed in connection with alternators, since these are almost always multipolar. Bipolar designs are, however, sometimes used in connection with turbine working, since the high speed of revolution calls for small numbers of poles, in order that the machine may conform to standard frequencies. For example, a machine running at 1500 rpm requires only 2 poles to provide a frequency of 25 cycles per sec, and similarly one making 3000 rpm gives 50 cycles per sec with 2 poles.

HEYLAND POLYPHASE GENERATOR, a three-phase alternator which, in the main, is similar to an ordinary machine, except that the windings of the revolving field-magnet are divided into six groups, connected with a commutator to which three sets of brushes are applied. The brushes are connected with two transformers, one of which is joined across the terminals of the generator-armature, and supplies a practically constant current, while the other has its primary in series with the armature winding, and supplies a current proportional to the wattless component of the armature current. The resultant excitation suffices for maintaining constant terminal pressure, even when the alternator is supplying an inductive load, and the generator is both self-exciting and self-regulating, after the manner of a compound-wound cc generator, as already described in this article.

ASYNCHRONOUS GENERATOR.—When an induction motor is mechanically driven at a speed above synchronism with the source of alternating electricity with which it is connected, it acts as a generator, producing alternating electricity at the same frequency as the original source. Such a machine under these conditions is called an *asynchronous generator*, and has the feature that it need not be synchronised before throwing into parallel with alternators of the ordinary type. On three-phase electric railways the motors, above certain speeds, become asynchronous generators when descending inclines, and return energy to the line.

General

Homopolar Generator.—Both continuous and alternating generators may be of the homopolar type. A *homopolar generator* is a type of electric generator in which all the poles facing one set of armature conductors are alike in polarity. Thus a line of force is never cut twice in one revolution by the same conductor, and the direction of the emf induced in a given part of any conductor is always the same. Only one field-magnet coil is necessary, no matter how many poles there may be, and in cc machines of this type, the poles may be continuous, so that the magnetic flux is invariable in direction and intensity. Cc homopolar machines are sometimes called *unipolar*, *nonpolar*, or *acyclic*. See Noegerrath Homopolar Dynamo; Unipolar; 'Inductor Type of Alternator' under Alternator; Nonpolar Generator.

A Self-regulating Generator is an electric generator (either for continuous or alternating electricity) which is provided with windings, or in some cases with mechanical devices, by means of which the current, pressure, or power is maintained constant, irrespective of variations in the load upon the machine. See Tirrell Regulator.

A Constant-pressure Generator is a generator which is either compound-wound or otherwise regulated, so that the pressure between the terminals shall be practically constant at all loads.

Constant-current Generator.—When it is required that a generator shall provide a current of constant intensity, not only is the field usually series-wound, but the armature is generally provided with a winding which, when traversed by the rated current, makes the armature reaction much greater than is customary in a constant-pressure machine. These proportions tend to give constancy to the value of the current independently of the value of the resistance of the external circuits. To render the current still more constant, it is customary to provide the machine with an automatic regulator. In the early days of electric lighting, constant-current generators were usually employed for arc lighting, the arc lamps all being connected in series. When the number of lamps in circuit was increased, the pressure at the terminals of the machine automatically increased, and the current remained constant. The most notable amongst these early constant-current generators were the Thomson-Houston arc-lighting dynamo and the Brush arc-lighting dynamo. Nowadays arc lamps are almost always operated from ordinary constant-pressure circuits, and there is no need for special generators for supplying them with electricity.

See Dynamo; Dynamo-electric Machine; Alternator; Motor; Rotary Converter; Motor-generator; Motor-converter; Polyphase Motor; Single-phase Motor; Unipolar; Noegerrath Homopolar Dynamo; Alternator, Pan-synchronous; Alternator, Compound-wound.

Generator, Alternating-current. See Alternator.

Generator, Brown's High-frequency Current. See Brown's High-frequency Current Generator.

Generator, Constant-power. See Constant-power Generator.

Generator, Double-current. See Double-current Generator.

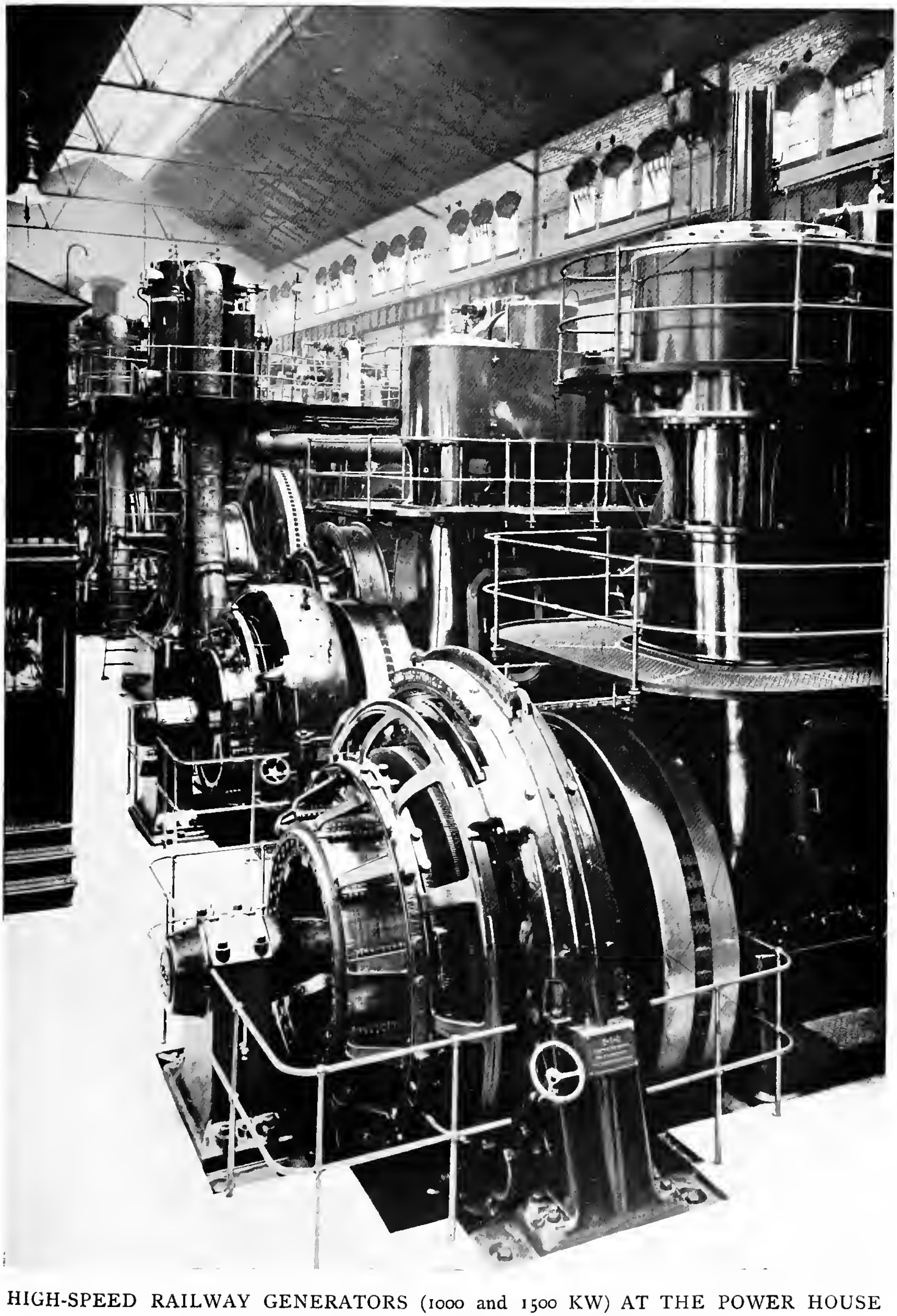
Generator, Polyphase. See Alternator, Polyphase; Alternator.

Generator, Railway. See Railway Generator.

Generator, Thermo-chemical Electric.—A number of cells have been devised, mostly containing carbon as one element, in which current is produced by the employment of chemical action at a high temperature. Their method of action is somewhat obscure, but appears to depend both on chemical and on thermo-electric effects. Various attempts have been made, mostly in America, to place a generator of this type on the market, but without success. [J. E-M.]

Generator, Thermo-electric. See Thermo-electricity.

Generator, Thermo-magnetic.—Current may be generated by the variation in



HIGH-SPEED RAILWAY GENERATORS (1000 and 1500 KW) AT THE POWER HOUSE OF THE SHEFFIELD CORPORATION TRAMWAYS

(By courtesy of H. E. Yerbury, M.Inst.C.E., Chief Electrical Engineer)

[*To face p. 242.*

magnetic induction caused by alternately heating and cooling a magnet. The method has not been commercially employed, though experiments have been made with this object. (See 'Inventions of Nicola Tesla', by T. C. Martin, New York, 1893.)

Generator Bus-bars. See Bus-bars.

Generator Panels of Switchboard, those panels of a switchboard which carry the instruments and apparatus for measuring and electrically controlling the generators. On a well-designed switchboard each generator has, as a rule, its own panel, which is generally of enamelled slate or of marble, from 35 mm to 50 mm thick, carried by an angle-iron framing, resting on the ground at the bottom, and supported at the top by stays reaching to the wall.

In the case of a cc generator, a good representative panel would have mounted upon it a reverse-current circuit breaker, an ammeter, a dp main switch (or perhaps a sp switch, since the circuit breaker could also be used as a switch), a dp socket into which a plug could be inserted to make connection with a voltmeter mounted on a swinging bracket at the end of the board; a rheostat handle, the spindle of which operates the shunt rheostat of the machine, the rheostat being placed either directly behind the spindle, if of small size, or lower down with chain-drive from the handwheel spindle, if of larger size; a field discharge switch and resistance, a lamp near the top of the panel for illuminating purposes, a fuse for the voltmeter socket, and, if desired, an integrating w hr meter. If the generator is compound-wound the equalising switch will generally be mounted on the frame of the machine; and in some cases the field rheostat is operated from a pillar mounted in front of the switchboard gallery. If the generator is for traction purposes, the circuit breaker is more often of the maximum-current type, and a lightning arrester is often added, without a choking coil, the choking coils as well as further lightning arresters being mounted on the feeder panels.

In the case of an ac ht plant of considerable size the bus-bars, oil switches, and the current and pressure transformers are generally mounted either in stoneware cells or on a suitable framework in an area guarded by expanded-metal walls, and no ht apparatus of any sort is brought on to the panels themselves. A typical three-phase generator panel is provided with three ammeters, one in each phase, operated from three current-transformers, one to each ammeter, a voltmeter, a power-factor indicator, and an integrating watt-hour meter, all operated from one or more potential transformers, and the necessary current transformers, the operating handle of the oil switch, which is connected to the switch itself by means of rods, two maximum releases operated by current transformers, or a reverse relay for automatically tripping the switch, lamps for indicating when the switch is tripped, a socket for taking the plug which makes connection between the secondary of a potential transformer and the synchroniser on the synchronising panel, and a lamp for illuminating purposes, while on the base of the panel or on a pillar at the front of the gallery is mounted the gear for the field circuit. This consists of a double-pole field switch and a discharge resistance, an ammeter, a handle for the rheostat in the generator field, and (if each generator has its own direct-coupled exciter) possibly also a small rheostat for the exciter field.

In some cases, where the capacity of the plant is not very great, the oil switch is mounted on the back of the panel, and the bus-bars, current transformers, &c., on the framework, also just at the back of the panel, but under no circumstances, in good modern practice, is ht apparatus permitted on the front of the board. Where the capacity of the plant is very large, the oil switches are operated electrically by means of small motors, and in this case the small switch-gear for starting and stopping this motor is mounted on the generator panel, also the lamp or lamps to indicate when the switch is open and when closed. (Ref. 'Standard Polyphase Apparatus', Oudin; also 'Electricity Control', Andrews.) [F. W.]

German Silver.—This is an alloy composed of copper, nickel, and zinc. It is very largely used as a resistance material in electrotechnics. Its specific resistance ranges from 20 to 30 microhms per cm cube. Its coefficient of increase of resistance per 1° C. is 0·00036 to 0·00044 of the resistance at 0° C. It is sold in the form of wire and of strip.

A sample tested by Feussner and Lindeck had, at 0° C., a specific resistance of 30 microhms per cm cube, and its resistance increased by 0·035 of one per cent per degree Centigrade increase in temperature. Its composition was as follows:—

Copper	60 per cent.
Zinc	25 „ „
Nickel	15 „ „

See HIGH-RESISTANCE ALLOYS; WIRE, RESISTANCE.

German-silver Resistance. See RHEOSTAT or RESISTANCE.

Gibb's End-discharge Carriage. See UNDERGROUND CONVEYOR, ELECTRIC.

Gilbert, a name proposed by the American Institute of Electrical Engineers (see Transactions, vol. xxii, p. 533) for the cgs unit of mmf; not generally accepted or used. See MAGNETOMOTIVE FORCE.

Giles Electric Valve. See RECTIFIER; CONDENSER, ELECTRIC; SWITCH, CONDENSER.

Girder-type Stator Frame. See FRAME, STATOR.

Glass, an amorphous transparent or translucent solid, composed of various silicates. That known as *sodium* or *soda glass* is the quality most generally employed for electrical purposes, being harder, and less hygroscopic, than *lead glass*. *Soda glass* has high dielectric strength, but permits a certain amount of surface leakage even when new, and is slightly soluble in rain-water. It is used for the manufacture of overhead line insulators, and to some extent for insulating purposes in the construction of Wimshurst machines, insulating stools, and similar apparatus, but when so employed, it should receive a coating of shellac varnish. (Ref. 'The Insulation of Electric Machines', Turner and Hobart; 'Conductors for Electrical Distribution', F. A. C. Perrine.) [H. D. S.]

Glimalac, the trade name of a mica-sticking varnish, which has, the manufacturers claim, great flexibility when unbaked, and becomes very hard when baked. These properties render it suitable for the manufacture of various mica products. See also MICA-STICKING VARNISHES; MICANITE; MEGOHMIT; MICA PLATE; MICA.

Globe.—An artificial source of light is often surrounded by a glass globe. This may serve protective purposes only, in which case a diminution of 6 per cent in the intensity of the light may be expected; if frosted, the loss may be 11 per cent. A globe is often used, especially for illumination by arc lamps, as a dispersing agent. Such globes are translucent and not transparent. The loss due to the opalescence is very considerable, but the shadows are not so intense, and the distribution is more even than with plain glass globes. (Ref. Franklin Institute Journal, vol. cxlix, 1900.)

FROSTED GLOBE.—The surface of a clear-glass globe may be irregularly roughened, either by the action of a sand blast or by some similar process, or by acid treatment, with the object of producing a surface which shall diffuse the light transmitted by the glass. Glass so treated is termed *frosted*.

OPAL SHADE OR GLOBE, a globe composed of semi-opaque glass, to which a white colouring matter has been added, with the object of softening or diffusing the light transmitted by it. Such globes may be of varying opacity, the less opaque types being known as *opalescent*.

HOLOPHANE GLOBES AND SHADES.—Frosted and opal globes and shades achieve their object in diffusing the light from the source enclosed by them, but in doing so they absorb a considerable amount of light. In order to diffuse the light, and yet transmit it as efficiently as possible, the *holophane* type of globe has been introduced. The surface of glass of this character is smooth, but is ribbed or grooved in such a way that the light is, during transmission, scattered in all directions by reflection and refraction by the minute prisms of which the glass envelope is composed. Moreover, the design of these minute prisms can be scientifically carried out so as to distribute the light in any desired direction, so that undesirable features in the nature of the distribution of the light from any source, can be greatly modified by this means. By suitable design a given glass surface can also be prepared in such a way as to either act as a reflector or transmitter. These shades are also known as the scientific glass ware for illumination purposes.

Globe Photometer. See PHOTOMETER, GLOBE.

Globe Strain Insulator. See INSULATOR.

Glow Lamp.—

['*Glow Lamp.*—A term recommended instead of incandescent lamp in order to avoid confusion with the *incandescent gas* mantle.'—I.E.C.

See also LAMP, INCANDESCENT ELECTRIC.

Glow-light Oscillograph. See OSCILLOGRAPH.

Gold (chemical symbol = Au), a metal worth £4, 6*s.* 6*d.* per troy oz. when of the purity corresponding to 24 carats. Its specific gravity is 19·3, and its specific heat is 0·032. Its melting-point is some 1100° to 1200° C. Matthiessen's tests showed, for a temperature of 0° C, a specific resistance of 2·04 microhms per cm cube, increasing by 0·37 per cent per degree Centigrade increase in temperature. Other tests of the specific resistance of gold and its alloys have yielded the following results:—

	Specific Resistance at 0° C.	Percentage Increase in Resistance per 1° C. Increase in Temperature.
Gold, 99·9 per cent pure, tested by Dewar and Fleming ...	2·20	0·38
Gold 90 per cent and silver 10 per cent, tested by Dewar and Fleming	6·28	0·12
Gold 67 per cent and silver 33 per cent, tested by Matthiessen	10·80	0·07

Gold of the purity purchased by the Mint costs £3, 17*s.* 10*d.* per troy oz. This corresponds to £125,000 per metric ton.

Gold-leaf Electroscope. See ELECTROSCOPE.

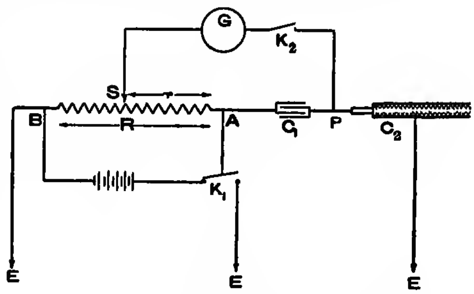
Goliath Electric Crane. See CRANE, ELECTRIC.

Goo, an electrolysable mixture of litharge with glycerine or vaseline mixed with water or alcohol, and with a few metal filings. It has been employed by De Forest as a wireless-telegraph detector.

Görges Method of Starting Induction Motors. See STARTING OF MOTORS.

Gott's Method of Measuring Capacity.—This method is generally employed for long cables. The standard condenser (C_1) of the fig. and the core of the cable (C_2) are joined in series with a high resistance AB, one end (B) of which is earthed. The battery is connected across this resistance through the key K_1, which connects the terminal A either to the battery or to earth.

The galvanometer G and a key K_2 are connected between a slider S on the resistance AB and the common point P between the condensers. If the slider S be moved to some position on the resistance AB, such that it is at the same potential as P, there will be no deflection of the galvanometer G on closing K_2. Now the fall of potential along the resistance AB is proportional to the resistance, and the fall of potential across the capacities in series is inversely as their capacities.



Gott's Method of Measuring Capacity

Hence if R = total resistance of AB, and r the reading of the slider at the position of balance, we have

$$\frac{r}{R-r} = \frac{C_2}{C_1} \text{ and } C_2 = \frac{r}{R-r} \times C_1$$

where C_1 is the capacity of the standard condenser, and C_2 that of the cable. The value of $\frac{r}{R-r}$ will vary with the duration of charging on account of leakage and absorption. Muirhead has introduced a modification of the test in order to correct for this.

Governor, Electric.—Electric governors have been applied to the regulation of turbines, steam engines, and electric motors. In principle they consist of an electrically-operated device, which, on a rise of pressure or current to a given value, closes a valve or inserts resistance in a circuit, so bringing down the pressure or current to its proper value; the reverse action taking place on a fall of pressure or current. (Ref. 'Dynamo-electric Machinery', S. P. Thompson.)

Graded Cable. See CABLE, GRADED.

Grading of Brushes. See BRUSHES, GRADING OF.

Grading of Insulation.—1. In an electric machine or transformer all parts of the working conductor are not at an equally great difference of potential from ground. Hence it would seem unnecessary to provide equally strong insulation at all points. For instance, if a three-phase transformer operates with the neutral point always grounded, the insulation at any place might be made simply proportional to the electrical distance of that place from the neutral point, being therefore greatest just at the terminals. This is known as *grading* the insulation. It is always possible, however, that circumstances may make it desirable to operate the apparatus with some other point grounded, or as a completely insulated system. In this case trouble would naturally arise. Graded insulation is employed to a certain extent on transformers, but practically never on dynamos or motors, as it would necessitate extra insulation space in certain slots, a condition which manufacturing considerations render difficult of attainment.

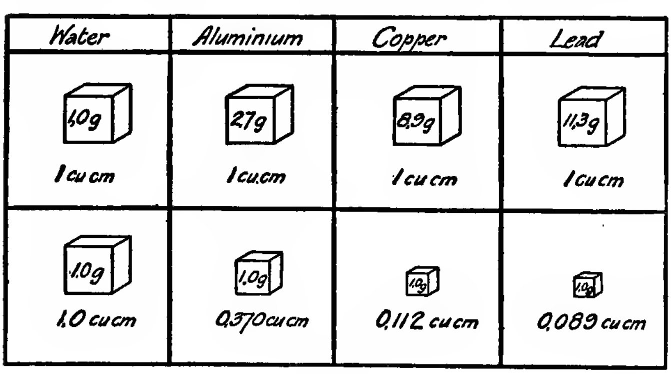
2. GRADING OF INSULATION is a term employed in cable manufacture to denote the use of material of relatively higher specific inductive capacity and dielectric strength near the conductor where the radius of curvature is small, than in the outer layers where the radius of curvature is large. By this means the stress is more uniformly distributed than would be the case were the insulation homogeneous throughout its entire depth. See CABLE, GRADED; FESSENDEN'S EXPERIMENT.

Grading of Voltages, the even distribution of the voltages of different districts over the range of pressures at which power is supplied by them, with a view to enabling lampmakers to utilise all the lamps manufactured by them, whilst at the same time the lamps supplied shall fall within narrow limits as regards cp and w at rated voltage.

Gram (preferable abbreviation = *g*), the weight of 1 cu cm of water.

1 g = 1 one-thousandth of 1 kg.
  = 1 one-millionth of 1 metric ton.

In the fig. are indicated, to six-tenths of full size, 1 cu cm of water, 1 cu cm of aluminium, 1 cu cm of copper, and 1 cu cm of lead. The weights in g are indicated upon their front faces. Directly below them are shown the volumes (in cu cm) of these substances which would weigh 1 g.



Gram

1 lb (avoirdupois) is equal to 453·6 g.
1 oz (avoirdupois) is equal to 28·35 g.

Gram-calorie. See CALORIE.

Gramme Ring. See ARMATURE.

Gramme-ring Armature. See ARMATURE.

Gramme Winding. See ARMATURE.

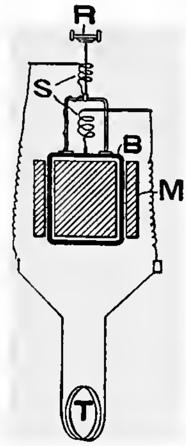
Graphite.—Graphite is used in electrical engineering for the following purposes: (1) As a lubricant. (2) As a preliminary coating in electrotyping. (3) In the manufacture of low-resistance brushes for the commutators and slip rings of dynamo-electric machines. These brushes have a relatively high conductivity at the brush contact, and lubricate the surfaces on which they run, but they are expensive, and often do not last so long as ordinary carbon brushes. (4) (Rarely) for the insulation of laminations. Graphite is very finely divided carbon, with sometimes a small percentage of mica. It is so soft that it can be worn down by the fingers to give an extremely thin coat. It has sufficiently high resistance to retard eddy currents, and allows some 3 to 4 per cent more active material for a given length of armature core than does paper. See also CARBON; RETORT CARBON.

Graphite Bushes for Trolley Wheel. See TROLLEY WHEEL.

Graphite Starting Resistance. See STARTING OF MOTORS.

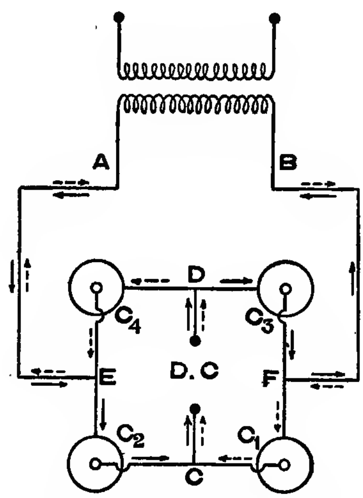
Graphitised Filament. See FILAMENT.

Grassôt Fluxmeter, an instrument for the exploration of magnetic fields. The field is traversed by a search coil T, in which an emf is thereby generated. The emf supplies current to a light coil B, in the body of the fluxmeter. B hangs in a uniform magnetic field (of the magnet M) by a suspension of cocoon-silk fibre, from a flat spiral spring R. Current is led into B by thin silver strips S. The spring R is employed only to minimise damage from shocks. Control is mainly effected by electromagnetic damping of the induced current in B, and this is the main principle underlying the theory of the instrument. The deflection of the coil B is proportional to the total flux passing through the particular search coil employed (many forms are possible). It reaches a well-defined maximum which is practically independent of the rate of moving the search coil. A scale reading is obtained (either direct reading or by mirror and reflected spot of light) which can be converted into maxwells from the calibration constant of the instrument, and into flux-density from the dimensions of the search coil.



Grassöt Fluxmeter

Grätz Method of Rectifying Current.— This method consists in employing four electrolytic rectifiers per phase, coupled in such a manner that both halves of the supply wave are utilised. The fig. shows the arrangement of the four cells in a sp rectifier. C_1, C_2, C_3, and C_4 are the four rectifier cells. They are coupled in such a manner that the



Grätz Method of Rectifying Current

two left-hand cells are in series, and are connected in parallel (but with poles opposed) to the two right-hand cells, which are also in series. The ac is fed-in at the centre points E, F of each of the pair of cells, and the pulsating unidirectional current is drawn from the junctions C, D of the parallel arrangement. Consider a current leaving the transformer by the terminal A at some instant: since the cell will only allow current to pass from lead to aluminium, the current will pass through C_2, then through the load, and back to terminal B by way of C_3. An instant later the current has reversed, and leaves the terminal B of the transformer, traverses C_1, then the external circuit in the same direction as before, and returns to terminal A through C_4. The direction of the current through the external load is therefore always the same, but varies between zero and its maximum value with twice the frequency of the supply. See RECTIFIER.

Gravity Control. See INSTRUMENT CONTROL.

Grease-spot Photometer Head. See PHOTOMETER HEAD, CONTRAST.

Great Calorie. See CALORIE.

Grid, Damping. See DAMPING GRID.

Grid of Accumulator. See ACCUMULATOR, GRID OF.

Grid Resistances, Cast. See RHEOSTATS OR RESISTANCES.

Grinding Rotor Cores.—In induction motors the gap is very small, and in order that the rotor surface may be perfectly true, it is frequently the custom to grind the surface with an emery wheel after the rotor has been completely wound, and is ready for assembly. This procedure is particularly necessary when a T notching die (see DIE) has been used to punch the rotor slots.

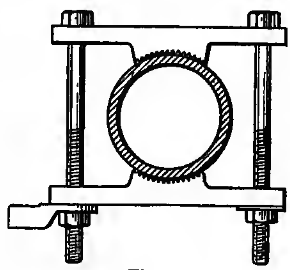


Fig. 1

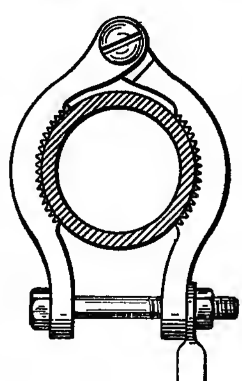


Fig. 2

Earthing Grips for Water Mains

Grips, Earthing (for Water Mains). — Two forms of a device for the purpose of obtaining a satisfactory connection between the main earth-wires of an installation and the water mains are indicated in figs. 1 and 2. Each consists in a suitable clamp, provided with a sweating socket. The sharp teeth on the inner surfaces of the clamp assist in obtaining a good contact with the water main. The grips have been devised by the Simplex Conduit Company. The form shown in fig. 1 is for mains up to 9 cm external diameter, and that shown in fig. 2 is for mains up to 4 cm diameter. See GROUND; GROUNDED WIRE; EARTH CONNECTION; EARTH-PLATE; CIRCUIT, EARTHED; CONDUCTOR, EARTHED; EARTHING; EARTHED.

Grisson Valve. See RECTIFIER.

Grondel Process of Ore Separation. See SEPARATION OF ORES.

Gross Core Length. See CORE LENGTH.

Grotthuss Hypothesis. See ELECTROLYSIS.

Ground, a connection from a conductor to earth, which maintains the conductor at earth potential. See GROUNDED WIRE; EARTH CONNECTION; EARTH-PLATE; GRIPS, EARTHING; CIRCUIT, EARTHED; CONDUCTOR, EARTHED.

['*Ground*, a term used in America, having practically the same meaning as earth.'—I.E.C.]

Ground in Commutator or Winding.—This fault, in continuous armatures, is often troublesome to locate. It not infrequently occurs in an intermittent form, only revealing itself when the armature is running and the conductors are subjected to centrifugal force. Under these circumstances a flashing test may reveal the position of the fault by burning it out. If, however, the ground is permanent, it may be detected by passing a fairly heavy current through the armature, and exploring with a voltmeter between the commutator bars and the frame of the machine. The position on the commutator which gives the lowest reading on the voltmeter indicates the position of the fault. See FAULT.

Ground Detector. See LEAKAGE INDICATOR.

Ground-plate. See EARTH-PLATE.

Ground Return. See EARTH RETURN.

Ground Wire, a wire used in making a ground (which see); a wire connected to an earth-plate, water pipe, &c., and so earthed in a thoroughly efficient manner. Such wires are used to earth transformer cases, frames of machines, lightning arresters, and other apparatus, and are run down the length of wooden line poles to form lightning protectors to the poles. In the latter case (and in this case only) a few turns of the wire round the base of the pole underground sometimes forms a sufficiently satisfactory earth connection, while at the top the wire is either attached to a suitable finial or is allowed to project above the top of the pole, and so form its own finial.

The term is also applied to a conductor stretched along the length of an overhead transmission line, above the line conductors, and earthed, its object being to protect the line from lightning, more particularly from the inductive effects of atmospheric electric charges. See GRIPS, EARTHING; GROUND; EARTH CONNECTION; EARTH-PLATE; GROUNDED WIRE.

Grounded Neutral. See NEUTRAL.

Grounded Terminal. See EARTH.

Grounded Wire, a wire connected to earth, and therefore at earth potential. The grounding may be intentional, as in the case of the guard wire on an overhead trolley system (see GUARD WIRE), and in the case of a wire run above a long-distance transmission line as a lightning protector. In other cases it is unintentional, as when the insulation of a conductor fails. When intentionally connected to earth, the wire through which the connection between the *grounded wire* and the earth is effected is termed the *ground wire* (which see).

Grounding. See EARTHING.

Group-charging of an Accumulator. See ACCUMULATOR, GROUP-CHARGING OF AN.

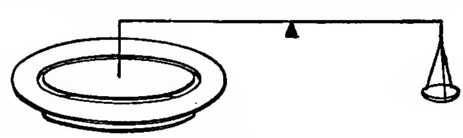
Grouping of Cells. See CELLS, GROUPING OF.

Grove, Battery. See BATTERY, PRIMARY.

Grove's Gas Battery. See BATTERY, PRIMARY.

Guard Cable. See GUARD WIRE.

Guard Ring.—In order to obtain even distribution of potential over a flat surface it



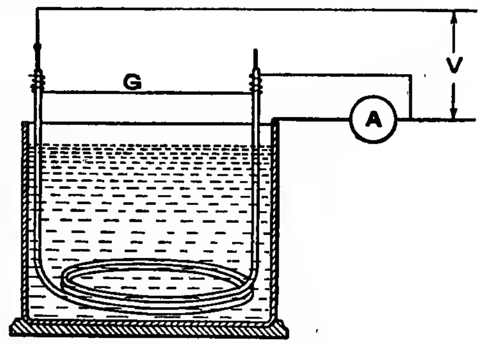
Guard Ring

is essential that the area considered should be a part of a much larger surface. If the part considered has to be capable of independent motion, as in the absolute electrometer, it must be connected with the larger surface by flexible metallic conductors. The outer surface is then spoken of as the *guard ring* (see fig.). See ELECTROMETER.

Guard Wire, wire placed above a tramway trolley wire or equivalent structure, where telephone, telegraph, or other lines cross it, in order to prevent a falling wire coming in contact with the live trolley wire, and so becoming raised to its potential of, say, 500 volts above earth. Such a pressure would, in many cases, lead to the burning out of telephone instruments or other apparatus, and to the risk of serious shock to persons on the telephone circuit. In the case of a single trolley wire, two guard wires are required, both about 24 in (some 60 cm) above the trolley wire, and one to one side of it and the other to the other side. In the case of two trolley wires near one another, two guard wires, as a rule, still suffice, but they are spaced rather farther apart than the trolley wires themselves. The guard wires run parallel to the trolley wires, and are supported by span wires stretched above the span wire carrying the trolley wire; or, where bracket arms are employed to carry the trolley wire, a small span wire to take the guard wires can be run between the pole and an upright attached to the end of the bracket arm. According to the Board of Trade Rules, the span wire must be at least as strong as 7/16 BWG mild-steel wire, and, as a rule, galvanised-steel wire is employed. Guard wire is sometimes insulated from the poles, but must be connected to the poles at least every five spans, and at least one pole so connected in this distance should in addition be connected to the rails, the object being to insure that the trolley wire is connected to earth and the corresponding circuit breaker opened, in the event of a falling telephone wire coiling round the guard wire and also making contact with the trolley wire.

Guard wires are also employed where a h pr overhead line crosses a road or other place where danger to life is likely to result from a broken wire or from a pole or other high object inadvertently being brought into contact with the wires when being carried in the vicinity of the line. Such guard wires are stretched below the live wires, and are cross connected at intervals so as to form a sort of protective netting. In some cases the guard netting or caging is carried all round the live wires (see also GROUNDED WIRE). (Ref. B.O.T. rules regarding Guard Wires, in The Electrician Directory; 'Notes on Overhead Equipment of Tramways', Messrs. Tweedy and Dudgeon; Journ.I.E.E., vol. xxxvii, No. 180, 1906; 'Electrical Traction', Wilson and Lydall.)

Guard Wire, Price's, used in tests of cable insulation resistance, to prevent surface leakage current at the cable ends from being measured as current passing through the insulation. The fig. shows diagrammatically



Price's Guard Wire

the guard wire G coiled on the insulation near the metal core of the cable, and connected to the circuit between the galvanometer (or milli-ammeter) A and the main.

Guide Block for Drawing Wires through Conduit, a block (see fig.) for guiding the wires and preventing the occurrence of twists or kinks in drawing wire into conduits. A twist or kink is undesirable, not only owing to the liability of its

Guide Block for Drawing Wire through Conduit

occasioning impairment of the insulation, but also owing to the difficulty of subsequently withdrawing from the conduit a kinked or twisted wire.

Guillotine Shears, a tool much employed by manufacturers of electrical machinery for cutting up sheet steel and insulating materials.

Gutta Gentzsch, the trade name of a gutta-percha substitute, invented for the insulation of submarine cables.

Gutta Percha.—This term was originally applied to the exudation from the *Dichopsis gutta*, but has been extended to the exudations collected from various trees belonging to the *Sapotaceæ* order. It is collected by allowing the sap which exudes from incisions made in the bark and branches of the trees, to dry in the sun. It is very extensively used as the dielectric for insulating submarine cables, and is apparently unaffected by continued immersion in water.

[H. D. S.]

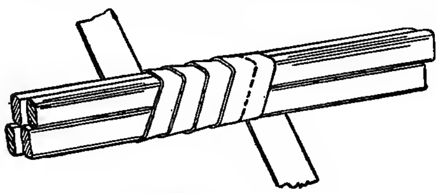
Guttaroid Tape, the trade name of an insulating tape made of vulcanised bitumen compound. It is used for insulating joints in vulcanised bitumen cables, and for sealing the ends of cables.

Guy Rope. See 'Wooden Line Pole' under LINE POLES.

H

Half-coiled Winding. See WINDING, HALF-COILED.

Half-overlapping in Taping Coils, a method of taping in which, as indicated in



Half-overlapping in Taping Coils

the fig., each successive turn of the tape covers the last turn by half the width of the tape.

Hammer Break. See COIL, INDUCTION.

Handcock and Dykes Limit Indicator, a device proposed by Messrs. Handcock and Dykes for use where electricity consumers are charged by the Contract Demand System (which see), and which comprises means whereby a resistance is thrown into the circuit, reducing the brilliancy of the consumer's lamps whenever he is exceeding his contract limit, and thus calling his attention to the circumstance, and rendering it necessary for him to switch off some lamps. (See paper by Handcock and Dykes entitled 'Electricity Supply Prospects and Charges as affected by Metallic Filament Lamps and Electric Heating', Journ. I.E.E., vol. xli, p. 332, April 9, 1908.) See CURRENT LIMITER.

Hand-regulated Arc Lamp. See LAMP, ARC.

Hand Regulator. See REGULATOR, POTENTIAL.

Hand Winding is a winding put into place, one turn at a time, by hand. It is a coil of such a design, or is so placed, that it is impracticable to wind it in a form and afterwards put the coil in place. A stator armature in process of being provided with a hand winding is shown in the fig.

Hand Winding

Hanger, Bracket-arm. See BRACKET-ARM HANGER.

Hanger, Insulated. See INSULATED HANGER.

Hangers for Accumulator. See ACCUMULATOR, HANGERS FOR.

Harcourt Pentane Lamp. See 'Pentane Standard Lamp' under STANDARD OF LIGHT.

Hard Copper. See COPPER; HARD-DRAWN COPPER WIRE; WIRE, COPPER.

Hard-drawn Copper Wire.—The Engineering Standards Committee defines *hard-drawn copper wire* as 'that which will not elongate more than 1 per cent without fracture'. This definition has been severely criticised. One criticism is contained in an article by Mr. Thomas Bolton published in the Elec. Rev. for Jan. 25, 1907. Mr. Bolton says:

'The Engineering Standards Committee in their report issued a short time back defined hard-drawn copper wire as 'that which will not elongate more than 1 per cent without fracture'. Unfortunately this definition, although probably correct as broadly representing the material under the conditions under which it is used, has caused considerable misapprehension, being quite inapplicable to conditions of practical testing with ordinary appliances. In the case of soft copper wire under stress, a steady permanent elongation takes place as the load is increased, practically throughout all the length of the piece under test, until the breaking-point is reached, when a local elongation takes place just at the spot where the wire breaks. The total elongation being large, this local elongation is small in proportion, and so the result is not materially affected by the length of the test piece. With hard-drawn wire, however, the actual increase of length while under stress is small until the point of fracture is reached, when a local elongation takes place as described above, which forms a large part of the total. Consequently, if elongation is measured up to actual fracture the percentage depends, through this cause alone, largely on the length of the test piece. Further, the test pieces ordinarily employed are not more than 8 to 10 in long, and since the total elongation to be measured is very small indeed, there is little doubt that although fairly uniform measurements are obtained, the readings are largely affected by unavoidable sources of error, and are a good deal higher than they should be, since it has been found that very much smaller figures are obtained by careful experiment upon pieces many feet in length.

'The Standards Committee's definition makes no mention of the length of the test piece, and without this it cannot be taken in the light of a specification with which hard-drawn copper wire will comply under ordinary conditions of testing with test pieces of moderate length, since under such conditions any such wire of good quality will show more than 1 per cent elongation before fracture. A difficulty in the way of any such general definition is that what is true of one size of wire is not true of another. What effect exactly the process of drawing has upon copper it would require a series of experiments of another nature to determine, but the effect appears to be twofold, viz. to increase the tensile strength and to increase the elasticity. The latter effect is almost nullified by subsequent annealing, and the former partially so. The action appears to be to some extent superficial, as the effect is less on a wire of large diameter than on one of small diameter, whose area is, of course, smaller in proportion to its surface.'

See Copper; Wire, Copper.

Hard Rubber. See Rubber.

'H' Armature. See 'Siemens H or Shuttle Armature' under Armature.

Harmonic denotes a component of a non-sinuous ac or alternating emf wave having a frequency higher than the normal. It can be shown that any such wave can be analysed into a number of sine components consisting of one fundamental term, and a number of other terms of higher frequency. As the + and − halves of such waves are symmetrical about the zero line, it is only possible to

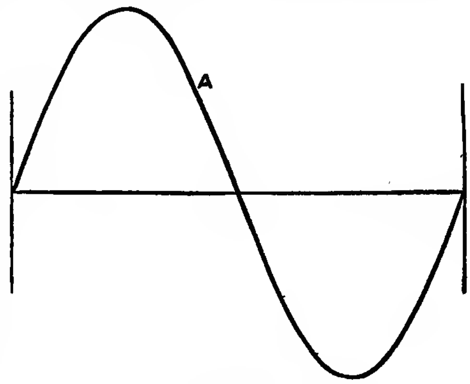


Fig. 1.—Fundamental Sine Wave

have harmonics of odd frequency. Hence the harmonic of lowest frequency is the one which completes three cycles to one fundamental cycle. This is usually called the *third harmonic* (though, speaking strictly correctly, it is the second if we regard the impossible double-frequency harmonic as the first). The next harmonic is the fifth, then

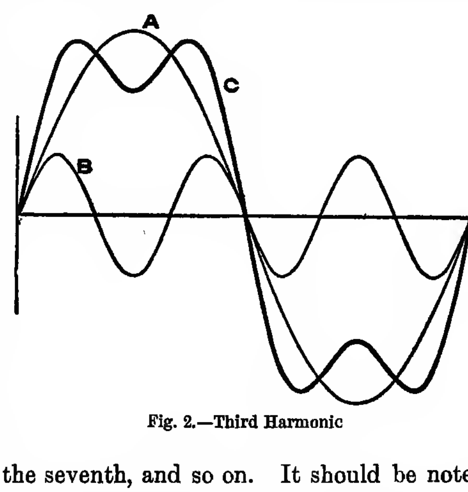


Fig. 2.—Third Harmonic

the seventh, and so on. It should be noted that the rms value of any wave is equal to the square root of the sum of the squares of the rms values of its components, whatever their phase relations may be. In fig. 1 is shown the fundamental sinuous wave. This is reproduced as the thin curve A in fig. 2, while the curve B represents a 'third harmonic', which, when its ordinates are added at every instant to those of A, gives the wave-form shown in curve C. This curve C is typical of an ac or emf wave with a 'third harmonic' component. In a similar way a 'fifth harmonic' is shown in fig. 3 by the curve D (as compared to the fundamental curve A), and by the instantaneous addition of A and

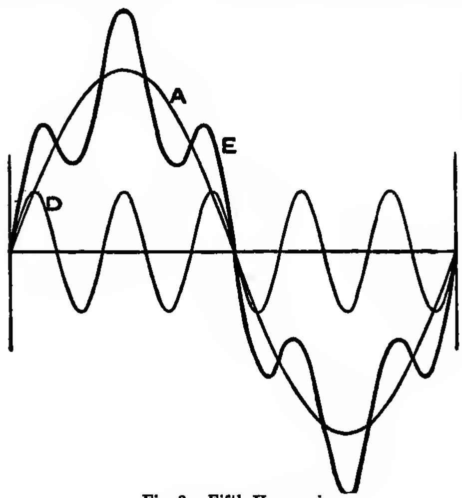


Fig. 3.—Fifth Harmonic

D a typical wave E is obtained having a 'fifth harmonic' component.

HARMONICS OF HIGHER ORDER, a term usually denoting harmonics of hf and small amplitude in relation to the fundamental curve on which they are superposed; ripples appearing in a wave form. See FUNDAMENTAL WAVES AND THEIR HARMONICS.

Hatch Accumulator. See ACCUMULATOR.

Hauling, Electric. See MINING EQUIPMENT, ELECTRICAL.

Heat, Mechanical Equivalent of. See JOULE'S EQUIVALENT.

Heat-dissipating Impregnating Materials.—These are employed for impregnating the cotton covering of conductors in armature and field coils to prevent their deterioration by heat. They render the covering more moisture-proof, increase its insulation resistance, and permit of employing a higher current-density in the conductors and consequent higher temperature, without damage to the insulation. In the case of field coils, they cement the layers and turns together, excluding air, and forming a more compact coil, which is able to more readily conduct the heat from the centre to the surface of the coil. See ELECTRO-ENAMEL; BERRITE; HEAT-EMISSIVITY OF VARIOUS MATERIALS OR SURFACES.

Heat-emissivity of Various Materials or Surfaces, the passage of current through a conductor causes the conductor to become heated to a greater or less degree. The number of heat units generated is proportional to the resistance of the conductor and the square of the current. The temperature to which the conductor rises depends upon the number of heat units generated, the specific heat of the material, the extent of the surface from which the heat can be radiated, and the emissivity of the surface, that is to say, its power of dissipating the heat into the surrounding atmosphere. The emissivity varies with different materials and different forms of surface. See HEAT-DISSIPATING IMPREGNATING MATERIALS; ELECTRO-ENAMEL; BERRITE; COOLING SURFACE.

Heat Insulation. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Heater, Electric.—An electric heater consists of a resistance either of metal or carbon, which becomes hot when traversed by a current, and which is so mounted in a suitable fitting as to radiate the heat to the best advantage. When a carbon resistance is used it is often arranged in the form of incandescent lamps, and sometimes in the form of blocks and rods.

Heating, Frictional. See FRICTIONAL HEATING.

Heating Coefficient.—The heating coefficient (sometimes termed the *heating constant*) is a figure used in the calculation of the temperature rise of conductors, and represents the rise of temperature in degrees per w lost per unit of radiating surface.

RADIATION COEFFICIENT OR CONSTANT.—The value of the heating coefficient depends upon the specific heat and the radiation coefficient which constitutes a measure of the emissivity of the surface. See HEAT-EMISSIVITY OF VARIOUS MATERIALS OR SURFACES; COOLING SURFACE.

Heating Effect of Currents.—The passage of current through a conductor generates heat in the conductor, the amount of heat being proportional to the resistance of the conductor and the square of the current. This phenomenon was formerly referred to as the *Joule effect*. See also HEAT-EMISSIVITY OF VARIOUS MATERIALS OR SURFACES.

Heating Effect of Electric Spark.—The electric spark due to disruptive discharge or the breaking of a circuit follows the usual law of the heating effect of currents. As the electric spark is due to a current passing through a medium of high resistance, it is intensely hot, sufficiently so, in fact, to ignite gas or fire explosives.

Heating Limit. See LIMIT TO OUTPUT OF DYNAMO-ELECTRIC MACHINES.

Heating of Cable. See CABLE, HEATING OF.

Heating of Electric Machines. See TEMPERATURE RISE OF ELECTRIC MACHINES.

Heating Rays. See LIGHT, INFRA-RED.

Hecnum Resistance Wire. See WIRE, RESISTANCE; HIGH-RESISTANCE ALLOYS.

Hedgehog Transformer. See TRANSFORMER, HEDGEHOG.

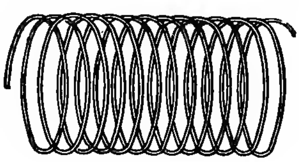
Hefner Standard. See STANDARD OF LIGHT.

Hekto-ampere Balance. See AMPERE BALANCE.

Helical Gear. See GEARING FOR ELECTRIC MOTORS.

Helion Lamp. See LAMP, INCANDESCENT ELECTRIC.

Helix, a coil of wire arranged to exert magnetising force when carrying current, or



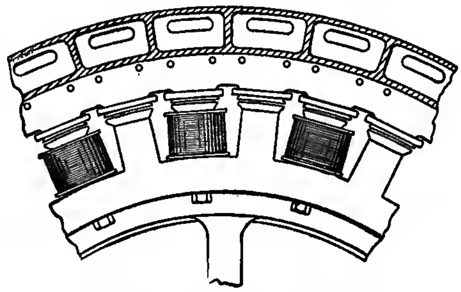
Helix

to offer inductive resistance to the passage of current (see fig.). See ELECTROMAGNET; COIL CHOKING; CHOKING EFFECT; COIL, KICKING; COIL, REACTANCE; SOLENOID.

Helmholtz Galvanometer. See GALVANOMETER.

Hemitropic Armature Winding. See WINDING, HEMITROPIC ARMATURE.

Hemitropic Construction of Magnets.—In hemitropic alternator magnet wheels only alternate poles, as shown in the fig., are provided with exciting windings. The advantage relates partly to the less cost of the windings, and partly to the circumstance that the unwound poles may be cast solid with the rim. A slightly greater weight of copper is necessary, and the arrangement has usually not been found satisfactory from a magnetic point of view, as the flux-distribution is more easily affected by the armature interference under load, and the leakage coefficient is higher. There is also less cooling surface with this type of



Hemitropic Construction of Magnets

field winding than with the type with one coil per pole.

Henry, the practical unit of inductance. It is used in the measurement of self and mutual induction, and is equal to 10^9 cgs units of the electromagnetic system. A coil has an inductance of 1 henry when the product of the number of lines enclosed by the coil and the number of turns in the coil when a current of 1 amp is flowing in the coil is equal to 100,000,000. Also a circuit has an inductance of 1 henry when a rate of change of current of 1 amp per sec induces an emf of 1 volt. 1 henry is equal to 10^9 cm. 1 henry is equal to 1 quadrant and to 1 secohm, these latter names having been formerly employed for the unit of inductance. See QUADRANT; SECOHM; INDUCTANCE; INDUCTION, SELF-; UNIT, PRACTICAL; UNITS, Q.E.S. SYSTEM OF.

Heræus Lamp. See LAMP, TUBULAR.

Héroult Electric Furnace. See FURNACE, ELECTRIC.

Hertzian Telegraphy. See WIRELESS TELEGRAPHY.

Hertzian Waves. See 'Electric Radiation' under RADIATION.

Hertz Oscillator. See OSCILLATOR, HERTZ.

Heterochromatic Photometry. See PHOTOMETRY.

Heteropolar Armature. See ARMATURE.

Heteropolar Magnet System, an expression used in contradistinction to a *homopolar magnet system* (which see), and applied to the usual type of construction in which poles of opposite magnetic sense (*i.e.* north and south) are alternately presented to the armature conductors.

Heterostatic Method, a method of using the quadrant electrometer in which the needle is charged, independently of the quadrants, to some high potential. The deflection is proportional to the difference of potential between the adjacent quadrants. See ELECTROMETER.

Heusler Alloys. — Heusler discovered that certain alloys which do not contain any of the magnetic elements exhibit marked magnetic properties, the permeability rising to as much as 1200 in some cases. All these alloys contain manganese, and the effect seems to be due to the presence of this element. Aluminium is also a frequent but not essential ingredient. It has been further shown that certain chemical compounds of manganese are magnetic, particularly the antimonide. Compounds of chromium also exhibit appreciable magnetic properties. (Ref. R. A. Hadfield, British Association Reports, 1904; J. A. Fleming and R. A. Hadfield, Proc. Roy. Soc., June, 1905; E. Gumlich, Elec., vol. lv, p. 94; C. A. Guillaume, Elec., vol. lvii, p. 707; J. M'Lennan, Elec., vol. lix, p. 844; M. Wedekind, 'L'Industrie Électrique', 1907.)

Heyland Diagram.—The circle diagram for the induction motor is often termed the *Heyland diagram.* See CIRCLE DIAGRAM; DISPERSION, MAGNETIC; BEHREND'S FORMULA.

Heyland Polyphase Generator. See 'Alternating Generators', under GENERATOR.

Hf, the preferable abbreviation for *high frequency.* See FREQUENCY, HIGH.

Hg, the chemical symbol for *mercury* (which see).

Hibbert Magneto-inductor Standard. —This instrument is used as a convenient standard of magnetic flux. It is independent of the earth's field, and does not require current measurements and other involved processes. It consists of a cup-shaped permanent magnet arranged to give a strong magnetic field in a narrow annular gap at the top. Through this gap is dropped by gravity a brass tube carrying on its lower edge a number of turns of silk-covered copper wire. A quantity of electricity which is proportional to the number of lines of force in the gap, the number of turns on the coil, and the resistance of the circuit is thus caused to flow through the external circuit. See GRASSOT FLUXMETER; TESTER, BISMUTH SPIRAL DENSITY.

Hibbert Standard Cell. See CELL, STANDARD.

Hidden Conductors. See CONDUCTORS, HIDDEN.

High Bar on Commutator. See COMMUTATOR BAR.

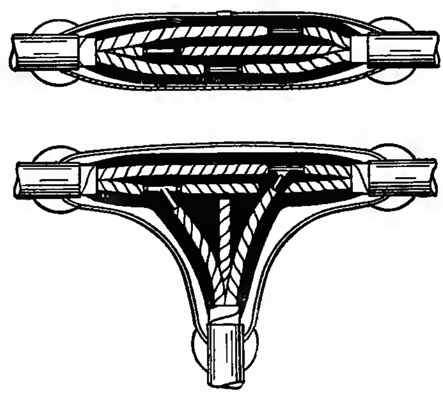
High Frequency. See FREQUENCY, HIGH.

High-frequency Current.—When the number of complete cycles of an ac is above 10,000 per sec, the frequency is usually said to be high. In the earlier days of electrical engineering, before the Elihu Thomson and Tesla discoveries, currents of 100 to 133 cycles per sec were known as *hf currents,* and those of 25 cycles per sec were known as *lf currents.* High frequencies are employed in wireless-telegraphy and telephony, in X-ray work, and in many other lines of investigation. See FREQUENCY, HIGH.

High-lift Centrifugal Pumps. See MINING EQUIPMENT, ELECTRICAL.

High Pressure. See PRESSURE.

High-pressure (or High-tension) Cable Joint.—Joints in ht insulated cables



Tee Joint for Extra High-tension Paper-insulated and Lead-covered Three-core Cable

are generally made in special cast-iron joint boxes (see fig.). The cables are passed into the box through suitable glands, or through chambers in the box which can be filled up with compound, &c.; inside the box the conductor portions of the cables are connected together by connectors or clamps. The box is then filled-in with compound, and the cover fixed down.

In some cases, but more rarely, a joint box is dispensed with; the conductors are then soldered together, sometimes with the help of connectors, the joints insulated with special impregnated tape, mica, &c., and the whole covered over with a lead sleeve, which is attached to the lead covering of the cables by wiped joints. (Ref. 'Distribution of Electrical Energy', J. F. C. Snell; 'Central Station Electricity Supply', Gay and Yeaman.) See CABLE, UNDERGROUND.

High-pressure Coil. See COIL, HIGH-PRESSURE.

High-pressure Current. See CURRENT, HIGH-PRESSURE.

High-pressure Main. See MAINS.

High-resistance Alloys. — A number of special alloys are now in use as resistance materials under a variety of more or less descriptive names. They aim chiefly at (1) cheapness, (2) fairly high resistivity, (3) low coefficient of change of resistance with temperature. Some account of certain of these will be found under their respective names. Amongst these are: beacon, constantan, eureka, German silver, hecnum, kruppin, manganese steel, manganin, nickelin, phosphor bronze, platinoid. See WIRE, RESISTANCE.

High-speed Telegraphy. See TELEGRAPH SYSTEMS.

High-tension Fuse. See FUSE.

High-tension Lines, Guard Wire for. See GUARD WIRE.

High-tension (or Pressure) Network. See NETWORK OF CONDUCTORS.

High-tension Switchboard. See SWITCHBOARD, CUBICLE (OR CELLULAR) TYPE OF HIGH-TENSION.

High-voltage Circuit Breaker. See CIRCUIT BREAKER.

High-voltage Insulator. See INSULATOR.

Highfield Booster. See BOOSTER; BOOSTER, REVERSIBLE.

Hissing Arc. See ARC.

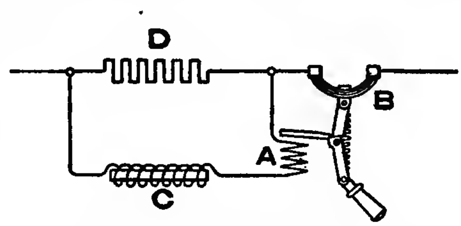
Hittorf's Tube.—A Hittorf's tube is of the same general construction, and is employed for the same purposes, as Crookes' tube, the Geissler tube, and the vacuum tube (which see).

Hobart Equipotential Connections. See CONNECTIONS, EQUIPOTENTIAL.

Hobart-Punga Method of Making Load-tests on Large Alternators.—It is an expensive matter to test a large alternator at its rated load. In the Hobart-Punga method, the equivalent of the rated load—so far as regards heating of the alternators—is obtained by running the alternator for a pre-arranged number of minutes on open circuit, but with more than normal excitation, and then for another pre-arranged number of minutes on short circuit, and with such low excitation as to occasion the circulation in the armature windings, of a current exceeding the normal current by the desired amount. By the adoption of suitable values for these various quantities, and by repeating the cycle for a sufficient number of hours, each part of the machine will arrive at the same temperature as would have been attained had the machine carried its normal load for this same number of hours. This method has also been employed in making heat tests on cc machines. (On p. 759 of the Elec. World and Engineer for April 22, 1905, the method is described in detail.)

Hobart's Methods of Starting Induction Motors. See 'Starting Induction Motors' under STARTING OF MOTORS.

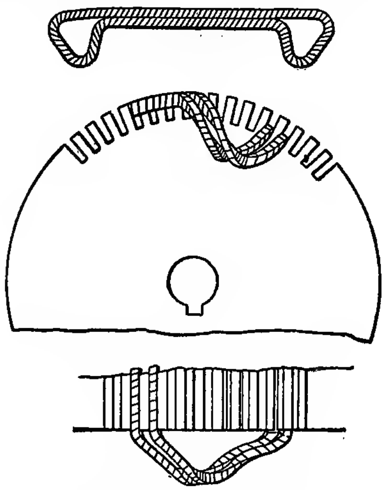
Hobart's Time-limit Device for Continuous-current Circuits. — The coil



Hobart's Time-limit Device for Continuous-current Circuits

actuating the switch is in series (see fig.) with a coil of suitable inductance, and these two coils are paralleled with a non-inductive path of suitable resistance. Thus it can be arranged that a heavy current of sufficient duration to divide between the two paths in proportion to their conductances shall not, if it last for but a few instants, suffice to actuate the switch, since the inductance coil will retard the growth of the current in that portion of the circuit in which the switch is located. The device is the subject of U.S.A. Patent No. 706,055 of August 5, 1902. See CIRCUIT BREAKER.

Hobart Type of End-connection, a design of armature end-connections forming the subject-matter of British Patent No. 17,489 of 1901. The connections (see fig.) are formed on the principle of an equilateral triangle bent out of its original plane, and with the corners rounded off and otherwise modified to adapt it to joining the two corresponding face conductors by an essentially three-sided equilateral end-connection as indicated in the fig. See COIL, FORM-WOUND.



Hobart Type of End-connection

Hoist, Electric. See LIFT, ELECTRIC; CRANE, ELECTRIC.

Holden Electrolytic Meter. See METER, ELECTROLYTIC.

Holden Permeability Bridge. See 'Bridges for Magnetic Measurements' under BRIDGES.

Holes, Ventilating or Air, in Core. —Instead of the usual radial ventilating ducts in an armature core, longitudinal holes have been recently tried, through which air is forced from one side of a machine to the other. It is claimed that by this method a better cooling effect is obtained, owing to the fact that the heat is conveyed to the cooling surface straight through the iron instead of from sheet to sheet across the sheet insulation, this last path being stated to be more than ten times as resisting to heat as an all-metal path. See DUCT, VENTILATING OR AIR; VENTILATION OF ELECTRICAL MACHINERY; DISTANCE PIECE.

Holophane Globe. See GLOBE.

Holophane Reflector. See REFLECTOR.

Home Office Mining Rules *re* Pressure. See PRESSURE.

Home Signal, the semaphore or other signal at the end of a section of line (or 'block'). See BLOCK SYSTEM FOR RAILWAYS.

Homopolar. See UNIPOLAR; GENERATOR; NOEGERRATH HOMOPOLAR DYNAMO.

Homopolar Alternator or Dynamo. See GENERATOR; 'Inductor Type of Alternator' under ALTERNATOR.

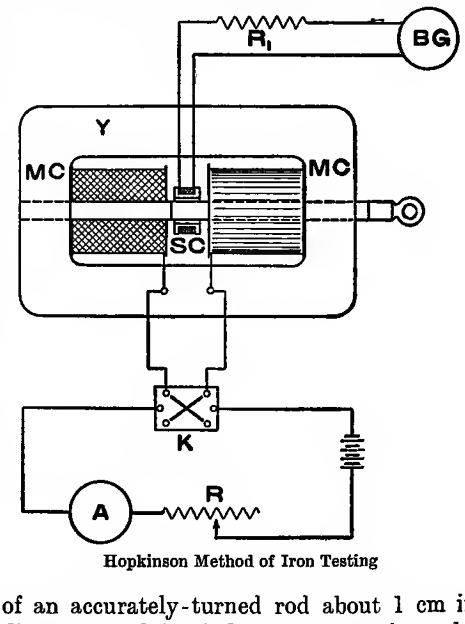
Homopolar Generator. See GENERATOR; NOEGERRATH HOMOPOLAR DYNAMO.

Homopolar Magnet System, one in which poles of the same sense only (*i.e.* either all 'north' or all 'south') are presented to an armature. Examples of this type are the usual form of inductor type of alternator—Mordey's and Ferranti's alternator and the homopolar type of continuous machine (which see). See also HETEROPOLAR MAGNET SYSTEM; GENERATOR; UNIPOLAR; NOEGERRATH HOMOPOLAR DYNAMO; 'Inductor Type of Alternator' under ALTERNATOR.

Homopolar Series Motor, a dynamo-electric machine of the homopolar type for cc. It is identical in construction with a homopolar dynamo, but has the field-magnet winding in series with the armature, and is used as a self-exciting motor. See MOTOR, SERIES-WOUND; GENERATOR.

Hookham Continuous-current Meter. See METER, HOOKHAM CONTINUOUS-CURRENT.

Hopkinson Method of Iron Testing. —In this method the specimen is in the form



Hopkinson Method of Iron Testing

of an accurately-turned rod about 1 cm in diameter, and divided into two portions, the butt ends being carefully faced to form a good magnetic joint. This divided rod is passed through accurately fitting holes in the ends of a massive rectangular soft-iron yoke, indicated by Y in the fig., which embraces the two magnetising coils MC through which the specimen also passes.

The inner faces of the magnetising coils are separated by a space about 1 cm long which receives the little search coil SC. When threaded by the specimen, it is held in position against a spring tending to throw it out. If now one-half of the specimen be slightly withdrawn, the magnetic joint is broken, and the search coil, being released by the withdrawal of the specimen, flies out and cuts the whole flux which had passed through the test piece. If, therefore, the search coil is connected to the terminals of the ballistic galvanometer BG, the throw of the instrument is proportional to the flux cut. R and R_1 are regulating resistances, A is an ammeter in the circuit of the coils MC, and K is a reversing switch. Precautions must be taken to demagnetise the specimen thoroughly, and the search coil and specimen should be replaced before any change in current value is made. See 'Bridges for Magnetic Measurements' under BRIDGES; DRYSDALE METHOD OF TESTING IRON AND STEEL; HUGHES INDUCTION BALANCE; RING METHOD OF MAGNETIC TESTING; STEP-BY-STEP METHODS OF MAGNETIC TESTING; PERMEAMETER; IRON AND STEEL TESTING.

Horizontal-plane Type of Aerial Transmitter. See TRANSMITTER.

Horn, Driving. See DRIVING HORN.

Horn, Pole. See POLE HORN.

Horn-break Switch. See SWITCH, HORN-BREAK.

Horn Fibre, a term applied to a tough fibrous material supplied in any thickness. It is manufactured in sheets approximately 0·004 in (0·1 mm) thick, which, to make the greater thicknesses, are adhered together under pressure. It depends for its flexibility on the moisture it contains, and if this is dried out it becomes brittle. It has a rough, hard surface, and is by no means uniform in thickness, but its good mechanical properties render it very suitable for slot linings. [H. D. S.]

Horn-type Lightning Arrester. See LIGHTNING ARRESTER.

Horse-power (preferable abbreviation = *hp*), a unit of power introduced by Watt, and equivalent to a rate of doing work of 76·0 kg m per sec. One hp is equal to 746 w. The use of the term *horse-power* must ultimately give way in favour of the term *kilowatt*, or of some other reasonable term.

INDICATED HORSE-POWER denotes the power delivered by the steam to the piston of a steam engine, or by the hot gases to that of a gas engine. This power is measured by means of an 'indicator' (invented originally by Watt), which draws a diagram showing the work done on the piston at each stroke. While hp and ihp were useful terms in the days of Watt, it is deplorable that engineers should so lack initiative that these terms should not long since have become obsolete.

ELECTRICAL HORSE-POWER denotes the output of an electric generator when measured in hp. It is sometimes convenient to use this term when considering the combined efficiency of a steam engine and generator, because the power exerted by the steam in the cylinder is also measured in hp. The term will soon be obsolete.

BRAKE HORSE-POWER denotes the hp output at the shaft of an electric motor or steam engine. Such power is frequently measured and absorbed by applying a friction brake to a pulley on the shaft. The term is fortunately doomed to become obsolete in the immediate future.

HORSE-POWER HOUR, a unit of energy or work which is equal to that done by 1 hp in an hour. 1 hp hr = 0·746 kw hr, *i.e.* 0·746 kelvin. The kelvin is a distinctly more suitable unit of energy, and is gradually coming into use.

Horse-power Meter, an instrument graduated in hp, and used chiefly in connection with motors. It may be either a wattmeter or an ammeter (the latter on the assumption that the voltage is known, and in the case of ac the pf also). These instruments are usually graduated in ehp, but sometimes in bhp, if the efficiency of the motor at various loads is known.

Horseshoe Filament. See FILAMENT.

Horseshoe Magnet. See MAGNET.

Hospitalier Ondograph.—This instrument is a development of the Joubert contact-method of measuring alternating wave forms. The principle on which the action is based consists in automatically charging a condenser from each 100th wave, and discharging it through a recording galvanometer, each successive charge of the condenser being automatically taken from a point a little farther along the wave.

The instrument is illustrated in figs. 1 and 2. A synchronous motor A, operated from the source the wave form of which is required, is geared, through gearing B, to a commutator D in such a manner that while

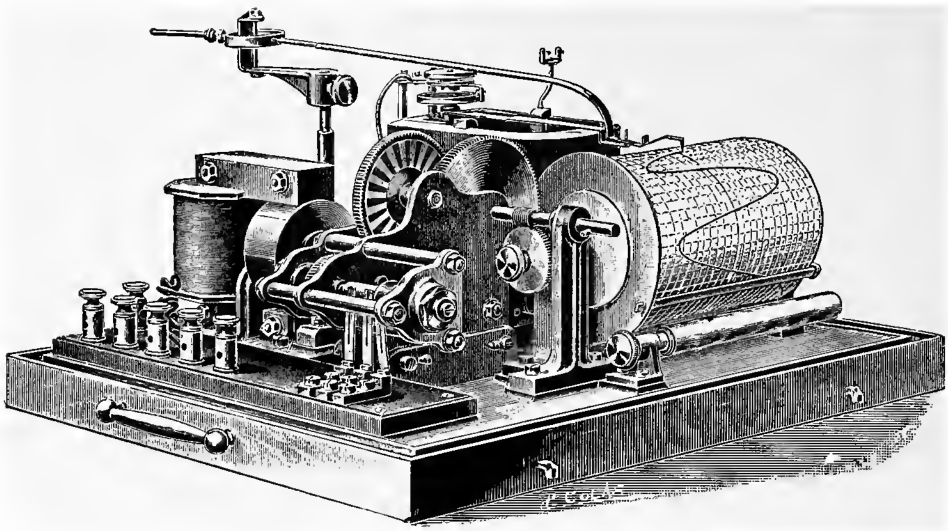


Fig. 1.—Hospitalier Ondograph

the motor makes a certain number of revolutions, the commutator makes a like number diminished by unity. Thus if the motor's speed is 1000 rpm, the commutator will have a speed of 999 rpm.

The commutator has three contacts, arranged to automatically charge the condenser *c c′* from the line, and discharge it through the galvanometer E, the deflection of which will be proportional to the pressure at any particular instant when contact is made.

In fig. 2 G G′ are the motor terminals, H H′ are connected to the condenser *c c′* through a resistance (to prevent sparking at the commutator), and I I′ are for connection to the source to be measured.

The recording galvanometer employed is

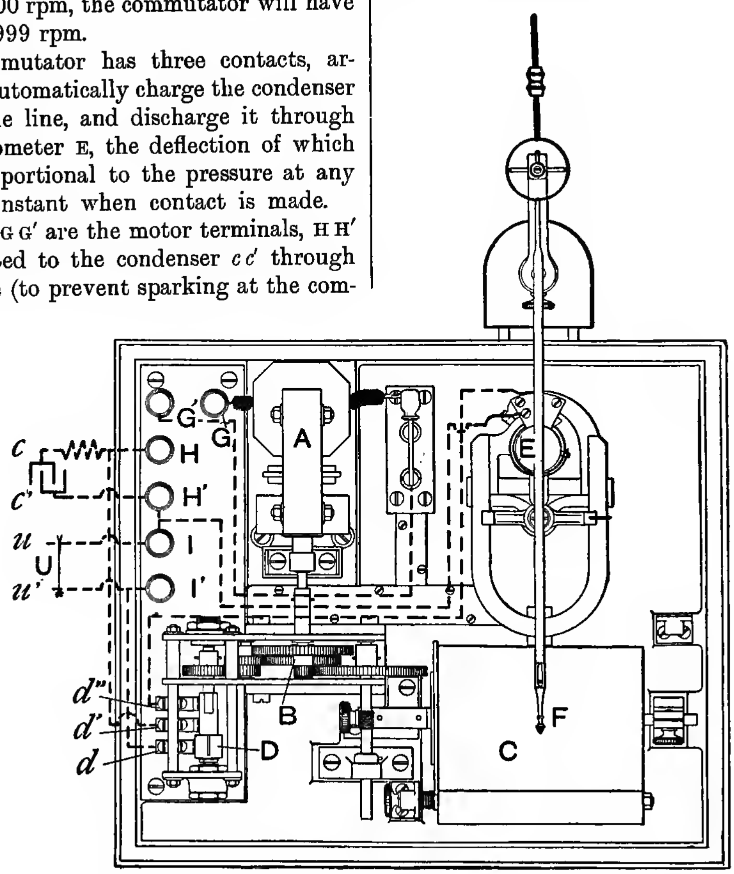


Fig. 2.—Hospitalier Ondograph

of the permanent-magnet type. Its moving coil E receives the discharges of the condenser in rapid succession and turns slowly from one side to the other. The movable part operates a long needle (separately mounted) carrying a pen F, which traces the curve on the rotating cylinder C. This cylinder is geared to the synchronous motor to run at such a speed as to register three complete waves upon its circumference. By substituting an electromagnetic galvanometer for the permanent-magnet galvanometer, and by using the magnet coils as current coils and the moving coil as the volt coil, the instrument can be made to draw watt curves.

Hospital Switch. See SWITCH, HOSPITAL.

Hot Vise, a vise whose jaws are heated either by steam or by electricity, and which is used for pressing armature coils so as to rid them of air spaces, and to give them a good rectangular shape before placing them in the slots. See PRESSING ARMATURE COILS; COIL, FORM-WOUND.

Hot-wire Ammeter. See AMMETER.

Hot-wire Regulating Mechanism of Arc Lamp. See LAMP, ARC.

Hot-wire Voltmeter. See VOLTMETER.

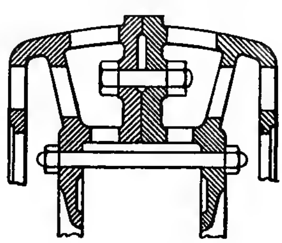
Hot-wire Wattmeter. See WATTMETER.

Hour Meter. See METER, HOUR.

Hour-meter System. See TARIFF SYSTEMS.

House-service Meter. See METER, HOUSE-SERVICE.

Housing, a frame casting (see fig.) in which the active core plates of an alterna-



Housing

tor or induction motor are assembled or housed. See FRAME, STATOR.

Hp, the preferable abbreviation for *horse-power* (which see).

Hp hr, the preferable abbreviation for *horse-power hour.*

H pr, the preferable abbreviation for *high pressure.* See PRESSURE.

Hr, the preferable abbreviation for *hour.*

Ht, the preferable abbreviation for *high tension.*

Hub, Armature. See ARMATURE HUB.

Hughes Coherer. See COHERER.

Hughes Induction Balance. — Two small coils in series are placed facing one another at a few inches apart on a baseboard. Between them is a suspended magnetic needle. The coils are wound in opposite directions so that similar poles face one another when a current flows through them. In series with the coils is a small variable resistance. A magnetised steel bar is placed on the baseboard with its centre in line with the centres of the coils, and is pivoted at its centre to turn in a horizontal plane, a graduated arc being on the baseboard under one end of the magnet. The object of the instrument is to test the magnetic qualities of samples of iron. In use, the coils are placed east and west of the needle, and their distances adjusted till their actions balance one another whatever be the current in them (the magnet being kept parallel to their planes at zero on its scale). The sample of iron is now introduced into one of the coils. The increased induction of magnetism disturbs the balance and deflects the needle. The magnet is then slowly turned till this is restored, *i.e.* till the needle points to its zero position. The amount by which the control-magnet has to be turned to effect this is a measure of the induction in the sample in arbitrary units. See 'Bridges for Magnetic Measurements' under BRIDGES; HOPKINSON METHOD OF IRON TESTING; DRYSDALE METHOD OF TESTING IRON AND STEEL; IRON AND STEEL TESTING.

Hughes Type-printing Telegraph. See TELEGRAPH SYSTEMS.

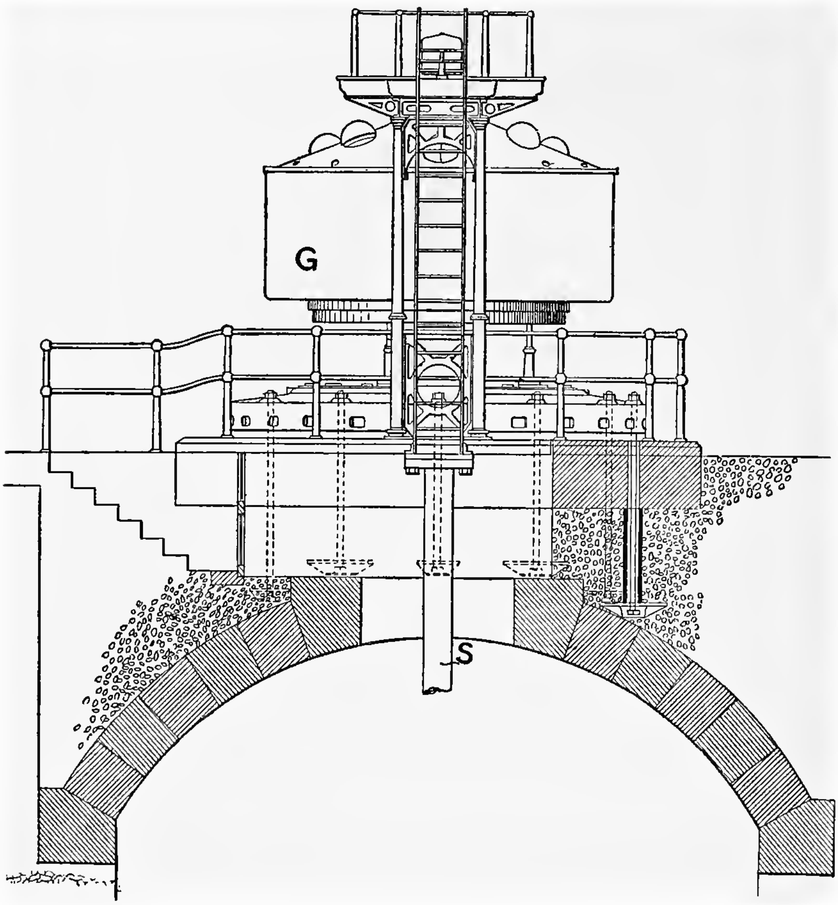
Humming Arc. See ARC.

Humming of Transformer, the sound produced in a transformer core, due to the rapid reversal of the magnetic flux. It may be caused partly by the contraction and expansion of the iron itself, and partly by the mutual attraction and repulsion of any loose core plates. The sound is often noticed on throwing a transformer into circuit, when, after commencing loudly, it gradually dies away. This is due to the high value reached in one direction by the flux, when the switch has been closed at a certain point in the emf wave. The flux remains partially or wholly unidirectional for some seconds, and only gradually becomes symmetrical about zero.

Hunting. See PHASE SWINGING; SURGING; CYCLIC IRREGULARITY; CRANK-EFFORT DIAGRAM; TORQUE DIAGRAM OF AN ENGINE; DAMPING GRID; AMORTISSEUR; DAMPING.

Hydraulic Accumulator. See ACCUMULATOR, HYDRAULIC.

Hydroelectric Generating Set, an electric generator driven by a hydraulic turbine. In the fig. G represents the electric generator of a hydroelectric generating set. The vertical shaft S extends down to the turbine.

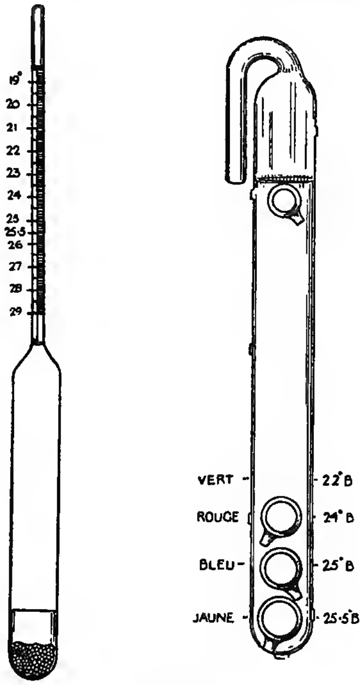


Hydroelectric Generating Set

Hydroelectric Generating Station. See 'Water Power' under CENTRAL STATION FOR THE GENERATION OF ELECTRICITY; MINING EQUIPMENT, ELECTRICAL.

Hydrometer, an instrument for measuring the specific gravity of the acid in an accumulator, and sometimes termed an *acidometer*. Assuming the specific gravity of water to be represented by 1, the usual range of readings on a hydrometer will be from 1·17 to 1·22. The specific gravity of the electrolyte will be higher when the cell is charged than when it is discharged. Hydrometers are made of various sizes according to the type of cell in which they are to be used, and instead of giving an exact reading, as in the type shown in the left-hand illustration, are sometimes provided with several coloured beads, which indicate within a few degrees the specific gravity of the electrolyte in which the instrument is placed. A hydrometer thus arranged is shown in the right-hand illustration. The calibration of these hydrometers is on the Beaumé scale. See HYDROMETER SCALES.

Hydrometer Scales.—It would be preferable were hydrometer scales graduated so that the specific gravity could be read directly from the scale. They are, however, often provided with one or other of certain arbitrary scales known as the *Beaumé*, *Beck*, *Cartier*, and *Twaddell*. The following tables



Hydrometers

are useful in ascertaining the specific gravity from such arbitrary scale readings:—

CONVERSION TABLE FOR THE SPECIFIC GRAVITY OF LIQUIDS LIGHTER THAN WATER

Specific Gravity.	Beaumé.	Beck.	Cartier.
0·75	48·0	56·7	—
0·80	36·0	42·5	43·0
0·85	25·4	30·0	33·6
0·90	16·0	18·9	25·2
0·95	7·0	8·9	17·7
1·00	0	0	11·0

CONVERSION TABLE FOR THE SPECIFIC GRAVITY OF LIQUIDS HEAVIER THAN WATER

Specific Gravity.	Beaumé.	Beck.	Twaddell.
1·0	0	0	0
1·1	13·2	15·4	20·0
1·2	24·2	28·3	40·0
1·3	33·5	39·2	60·0
1·4	41·5	48·6	80·0
1·5	48·4	56·7	100·0
1·6	54·4	63·7	120·0
1·7	59·8	70·6	140·0
1·8	64·5	75·6	160·0
1·9	68·6	80·5	180·0
2·0	72·6	85·0	200.0

Hysteresimeter, Blondel. See BLONDEL HYSTERESIMETER; GRASSOT FLUXMETER.

Hysteresis.—Magnetic Hysteresis: (1) A term expressing the fact that the magnetism in iron tends to lag behind the change which occurs in the magnetising force producing it, even when such change occurs very slowly. (2) The loss of energy in a given mass of iron due to this cause when the iron is subject to magnetic reversals (see HYSTERESIS LOOP).

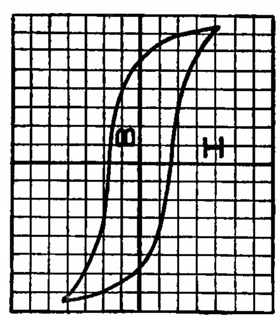
Hysteresis, Linear. See LINEAR HYSTERESIS.

Hysteresis, Viscous, apart from eddy-current loss, any increase which may occur in the hysteresis loss per reversal, in iron, due to increase in frequency of magnetisation.

Hysteresis Coefficient. — (Steinmetz coefficient.) That factor which gives the iron loss (through hysteresis only) in ergs per cu cm per cycle when multiplied by the 1·6 power of the induction density. It is denoted by η. See HYSTERESIS LOOP.

Hysteresis due to Rotating Magnetic Flux, the loss of energy in ergs per cu cm through hysteresis when the direction of magnetisation is rotated once without changing its intensity. This loss becomes very small if the flux density exceeds 22,000 lines per sq cm. See 'Core-loss Curves' under CURVE, CHARACTERISTIC.

Hysteresis Loop, a curve (see fig.) expressing the relation between magnetising



Hysteresis Loop

force H and resulting magnetisation or induction density B, when the magnetism is reversed between equal and opposite limits of magnetisation. The area of such a loop, taken to scale and divided by 4π, is equal to the energy loss in ergs per cu cm per cycle, arising through hysteresis. See HYSTERESIS COEFFICIENT.

Hysteresis Loss. See LOSS, HYSTERESIS.

Hysteresis Tester. See EWING HYSTERESIS TESTER; TESTER, EPSTEIN HYSTERESIS; BLONDEL HYSTERESIMETER.

Hysteretic Coefficient. See HYSTERESIS COEFFICIENT.

Hysteretic Index, the power to which the induction-density limits of magnetisation must be raised in order to obtain proportionality with the hysteresis loss. See LOSS, HYSTERESIS; HYSTERESIS COEFFICIENT.

Hysteretic Torque. See TORQUE, HYSTERETIC.

I

I, the most widely employed symbol for designating current. It is distinctly preferable to employ I, the first letter of the word *intensity*, instead of C, the first letter of the word *current*, since C is so much more frequently employed for other purposes. The use of I instead of C is now widely accepted as the best practice.

'Ideal' Overload Capacity of Induction Motors, the maximum load of which an induction motor is capable, as measured on the elementary circle diagram, thus neglecting the loss in the primary winding and the core losses. See CIRCLE DIAGRAM.

Idiostatic Method, a method of using a quadrant electrometer in which the pressure to be measured is connected to one pair of quadrants and to the needle. In this case the deflection is proportional to the square of the difference of pressure between adjacent quadrants. The other method, namely connecting the pressure to the two pairs of quadrants, and giving the needle an independent permanent charge, is called *heterostatic* (which see). See ELECTROMETER. (Ref. 'Electrostatics and Magnetism', Thomson (Kelvin).)

Idle Current.—In ac work the term *idle current* is applied to that portion of the current which is not in phase with the impressed emf, and which is due to capacity or inductance effects in the cables or other apparatus in the circuit. These currents do not directly consume power from the prime mover, but they set up ohmic losses in the conductors, and these losses have to be made good by the prime mover. They also increase the size of generator required for a given energy output. Capacity and inductance effects are of an opposite nature; the one tends to produce leading, and the other lagging, currents. Consequently idle currents may be eliminated by a proper balancing of the capacity and inductance. See CURRENT, COMPONENT; CURRENT, LEADING; CURRENT, WATTLESS; CURRENT, CONDENSER; CAPACITY CURRENT; FARAD.

Idle-current Ammeter and Wattmeter. See INDICATOR, PHASE OR POWER FACTOR; ELECTROGONIOMETER.

Idle Wire, that portion of the winding on a dynamo-electric machine which does not cut lines of magnetic force, *e.g.* the end-connections of an armature winding. See ENDCONNECTIONS; DEAD WIRE.

Igranic, a trade name applied to a widely used line of motor starters and rheostats. See STARTING OF MOTORS; RHEOSTATS.

Ihp, the preferable abbreviation for *indicated horse-power*. See HORSE-POWER.

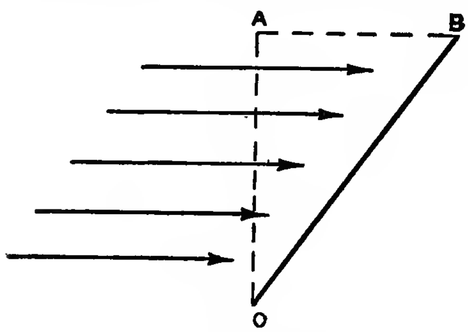
Ilgner System of Electric Winding. See MINING EQUIPMENT, ELECTRICAL; ENERGY, KINETIC, OF FLYWHEEL; FLYWHEEL STORAGE.

Illuminated-dial Instrument. See DIAL INSTRUMENT, ILLUMINATED-.

Illuminating Engineering is the term used to describe the application of scientific principles to the proper distribution and use of light for purposes of illumination. The specialist devoted to the study of this question has been termed an *illuminating engineer*. His province consists in considering and advising on all questions connected with the above subject, and in studying in an impartial manner the best methods of employing an illuminant, so as to secure a certain result.

Illumination.—Solomon at p. 30 of his treatise entitled 'Electric Lamps' defines this term as follows: 'The illumination produced by a source of light on any surface is the flux of light falling on the surface, divided by the area of the surface'. The same author defines 'flux of light', or 'luminous flux', as the quantity which measures the rate of radiation from the source, and states that 'unit flux exists when light is radiated with unit intensity in a beam of unit solid angle, but this unit is, however, rarely used; the spherical cp is used instead; it is the total flux when light is radiated with unit intensity in all directions, and is therefore 4π times the correct unit. The *quantity of light* produced by a source is the product of the luminous flux, and the time during which the flux is produced. Its unit is the *spherical candle-power-hour*, or the *spherical candle-hour.*' The 1896 Geneva Congress proposed the lumen-hour as the unit of quantity of light. It is equal to $\frac{1}{13\cdot 8}$ candle-hours.

Illumination, Cosine Law of.—If radiation falls perpendicularly on a surface O A, and produces an intensity of illumination



Cosine Law of Illumination

I per unit area, it will produce on a surface O B an intensity of illumination $I \times \frac{OA}{OB}$ per unit area; A B being perpendicular to O A.

A O B is equal to the angle of incidence on O B, and $\frac{OA}{OB} = \cos AOB$.

$\therefore I_\theta = I_0 \cos\theta$ where I_θ is the illumination on a surface on which the angle of incidence of radiation is θ, and I_0 is the illumination when the incidence is normal. See ANGLE OF INCIDENCE.

Illumination Photometer. See PHOTOMETER.

Illuminometer. See PHOTOMETER.

Image, Electric.—To obtain the distribution of electricity induced on a conducting surface by a charged body, it is sufficient to imagine an oppositely-charged body situated on the other side of the surface in the position which would apparently be occupied by the optical image of the first body if the surface were a mirror. The lines of electric force are then drawn from the body to the image through the surface, and afterwards the imaginary part obliterated, leaving the lines between the body and conductor only.

Immersed Rheostat. See RHEOSTAT.

Impedance, the ratio of the rms voltage to the rms current in a conductor or apparatus carrying ac. Impedance is compounded of two elements, viz. resistance and reactance, these being in quadrature in the alternating cycle. Thus if I be the current, r the resistance, x the reactance, and z the impedance; the emf is $I \times z$, the component in phase with the current is $I \times r$, whilst the component in quadrature with the current is $I \times x$. Also $z = \sqrt{r^2 + x^2}$.

The components of an impedance made up of a number of impedances in series are the sums of the corresponding components of the several impedances. The unit of impedance is the *ohm* (which see), and the equivalent of Ohm's law for ac may be written as follows:—

$$I = \frac{E}{\sqrt{r^2 + 4\pi^2 \sim^2 l^2}}$$

where $\sim$ is the frequency (cycles per sec), E is the voltage, and l the inductance of the circuit. The quantity forming the denominator of the right-hand side of this equation is the impedance of the circuit.

Capacity in a circuit exerts an influence opposite to that of inductance in a circuit. Denoting the capacity in farads by f, then the impedance of a circuit containing both inductance and capacity is the denominator of the right-hand side of the following equation for the current in the circuit:—

$$I = \frac{E}{\sqrt{r^2 + \left(2\pi \sim l - \frac{1}{2\pi \sim f}\right)^2}}.$$

Consequently, when the inductance and capacity in a circuit are of such values that

$$2\pi \sim l - \frac{1}{2\pi \sim f} = 0,$$

i.e. that
$$l = \frac{1}{4\pi^2 \sim^2 f},$$

then the current flowing is

$$I = \frac{E}{r}.$$

Impedance, Oscillatory, denotes the impedance of a conductor or circuit which carries an ac of very hf. In such a case the resistance of the conductor is very much increased, owing to the current being superficial (see SKIN EFFECT). Also the reactance of the conductor is diminished, owing to the absence of any appreciable magnetic field within the material of the conductor.

Impedance, Primary. See PRIMARY IMPEDANCE.

Impedance Coil. See COIL, CHOKING.

Impedance Factor denotes the ratio of the impedance of an inductive circuit to its resistance, or impedance factor equals

$$\frac{\sqrt{p^2 l^2 + R^2}}{R},$$

where $p = 2\pi \times$ periodicity,
$l =$ inductance in henrys,
$R =$ resistance in ohms.

Impedance factor is the inverse of pf. The term is infrequently used. See also IMPEDANCE; POWER FACTOR; INDUCTANCE FACTOR.

Impedance of Steel Rails.—In electric traction with ac the return circuit is usually formed by the track rails, which, owing to their high magnetic permeability, have a large inductance. In consequence of this, the current is mainly confined to the outer layer of the metal, a few mm thick, and the effective resistance of the rails is greatly increased, as compared with the actual resistance measured with cc. The effective resistance multiplied by the rms current gives the loss of power in the rails in w. On the other hand, the drop of pressure in the rails is determined by the product of the current and the impedance; the latter is the vector sum of the effective resistance and the reactance of the rails. Owing to the complicated nature of the problem, the effective resistance cannot be accurately determined by calculation; neither can the reactance. Experiments are therefore relied on to ascertain these values. (Ref. Elec., Feb. 23, 1906, and July 27, 1906; Proc.I.C.E., 1906–7; 'Electric Railway Engineering', pp. 280–5, Parshall and Hobart.)

Impedance Test, Static.—A stationary impedance test is sometimes made on the armature of an alternator, the current being supplied from an outside source. It will be found that, under these conditions, the impedance varies for different positions of the poles. The deduction of a value for the running impedance, from static impedance observations, does not give satisfactory results, and the test is more of value in checking a machine with previous ones of similar type. For this purpose, however, a measurement of the static impedance of the armature with the magnet system removed is more to be recommended.

RUNNING IMPEDANCE TEST, a test made on an alternator at normal speed with the stator short-circuited. The field excitation under these conditions has a value corresponding to the armature strength in ats added to the ats necessary to generate the impedance-voltage of the armature. No accurate note need be made of the speed during this test, as the short-circuit current for considerable ranges of speed above and below the normal only varies slightly. See also CURRENT, SHORT-CIRCUIT. [H. W. T.]

Impedance Voltage. See VOLTAGE, IMPEDANCE.

Impedance Volts of Alternator.—When currents are passing through the armature of an alternator at work a complicated system of cross and leakage fluxes of various frequencies is set up throughout the machine. These affect the terminal voltage of the machine, *i.e.* they act as an impedance of a more or less variable nature in the path of the current. In order to facilitate excitation and regulation calculations, it is convenient to express this variable impedance at such a simple constant value as shall produce an effect under given loading conditions, which will be equivalent to the complicated reactions which actually take place. This value is known as the *impedance volts of an alternator*, and usually varies with different pf. It is a maximum at zero pf, which is the condition under which the short-circuit test is made.

PERCENTAGE IMPEDANCE VOLTS OF AN ALTERNATOR.—If the impedance of an alternator, as defined above, is multiplied by the normal current, and if the voltage thus obtained is expressed as a percentage of the normal voltage of the machine, some indication is obtained of the regulating properties of the machine. [H. W. T.]

Impregnated Carbons. See CARBONS, ARC LAMP.

Impregnated Cloths and Fabrics. See IMPREGNATED INSULATING MATERIALS; CAMBRIC FOR INSULATING PURPOSES; EMPIRE CLOTH; VARNISHED-CAMBRIC TUBE; VARNISHED-CAMBRIC CABLE; INSULATING COMPOUND.

Impregnated Insulating Materials.—These include the numerous treated cloths and papers at present on the market. Their insulating properties depend on the nature of both the impregnating and the fibrous materials and on the method of impregnation. The cloth or paper serves as a framework to hold the impregnating material, which increases the dielectric strength and renders the cloth or paper moisture-proof.

Impregnation mechanically weakens cloths and papers, but enables them to withstand the destructive action of heat for a longer time. See EMPIRE CLOTH; OILED LINEN; OILED PAPER; PAPER FOR INSULATING PURPOSES; CAMBRIC FOR INSULATING PURPOSES; VARNISHED-CAMBRIC TUBE; VARNISHED-CAMBRIC CABLE; HEAT-DISSIPATING IMPREGNATING MATERIALS; INSULATING COMPOUND; IMPREGNATING VARNISHES; VACUUM DRYING OVEN.

Impregnated-jute Cable. See CABLE, UNDERGROUND.

Impregnating Compound. See INSULATING COMPOUND.

Impregnating Varnishes.—These are baking varnishes employed for vacuum impregnation, and differ only from the ordinary insulating baking varnishes in their constituents. The solvent used for thinning should not be too volatile a spirit, or there will be considerable loss by evaporation, and their consistency needs careful attention. See also HEAT-DISSIPATING IMPREGNATING MATERIALS; VACUUM DRYING OVEN.

Impressed Electromotive Force. See ELECTROMOTIVE FORCE, IMPRESSED.

In, the preferable abbreviation for *inch* or *inches*.

Incandescence, the property of matter whereby, when it is brought to a sufficiently high temperature, radiation, visible to the eye, is emitted from it.

As the temperature of a solid is raised, radiation of long wave length is first emitted, This radiation becomes more intense, and as the temperature rises, radiation of continually shorter wave length is added. It appears that though red rays are first emitted, yet on account of the superior sensitivity of the eye for green light, this is perceived first, and orange and red are seen afterwards, as their intensity increases. Then the radiation of shorter wave length up to the blue is added, and finally violet and ultra-violet at about 1200° C. Luminous radiation appears to be visible under 400° C. with certain metals (see 'Treatise on Photometry', Palaz, § 10). See also RADIATION. [E. H. R.]

Incandescent Cap. See CAP OF INCANDESCENT LAMP.

Incandescent Electric Lamp. See LAMP, INCANDESCENT ELECTRIC.

Incidence, Angle of. See ANGLE OF INCIDENCE.

Inclined Carbons. See CARBONS, ARC LAMP.

Incoming Alternator. See ALTERNATOR, INCOMING.

Index Press, a press in which the work is fed forward step by step, and at each step is punched in the same manner. Such a press is used for notching, one at a time, the several slots in an armature-core segment, which has been previously blanked. See DIE.

Indiarubber. See RUBBER.

Indicating Wattmeter.. See WATTMETER.

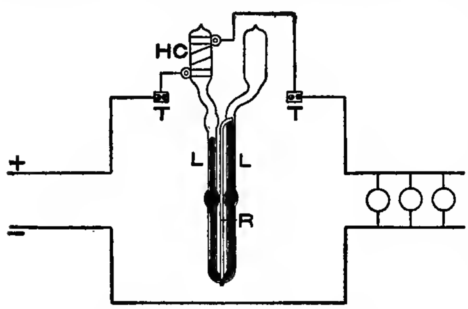
Indicator, Frequency. See FREQUENCY INDICATOR OR METER.

Indicator, Leakage. See LEAKAGE INDICATOR.

Indicator, Limit. See CURRENT LIMITER; HANDCOCK AND DYKES' LIMIT INDICATOR.

Indicator, Maximum-demand, an instrument used in the maximum-demand system of charging for electrical energy (see TARIFF SYSTEMS) in addition to the usual electricity meter. It registers the maximum current taken in a circuit during a given period (quarter or half-year); and its scale not only gives these currents, but also the maximum-demand units corresponding to them, based on the particular supply-pressure and the duration of the demand. The actual units consumed are registered in the usual manner by the meter proper, while the indicator gives those units which have to be consumed during the given period (quarter or half-year) before the low price per unit is charged. The instrument is based on the thermal, or electromagnetic, action of a current, or on the principle of intermittent integration. Whatever the principle used, the indicator should be made so sufficiently slow in its action that it shall not register *temporary* overloads, or the current taken by lamps switched on for a few minutes only, and its time-lag (sluggishness of action) should depend on the nature of the circuit (incandescent lamps, or motors, &c.). It has to be re-set to zero at the end of each quarter.

Wright Maximum-demand Indicator.—The maximum-demand indicator invented by Arthur Wright, is based on the thermal action of a current. It is a differential thermometer consisting of a U-tube filled with a solution of strong sulphuric acid and terminating in two sealed bulbs. The accompanying fig. gives a diagrammatic sketch and the method of connection of the instrument. TT are the terminals. LL are the two limbs of the U-tube. The left-hand bulb is wound with the heating coil HC through which the circuit current flows. The heat produced in this coil causes the air to expand and force the liquid to rise in the right-hand limb until it overflows into the reading tube R attached to the latter. The ultimate height of the



Wright Maximum-demand Indicator

liquid column in the reading tube depends on the maximum current, and the scale attached to it (not shown in the diagram) gives the currents and the corresponding demand units at the particular pressure and based on the duration of the demand. The tubes are hinged at the terminals, in the instrument case, so that they can be tilted to re-set the instrument to zero, when the liquid flows back from the reading tube, into the right-hand bulb. The natural sluggishness of the instrument can be suitably increased by using an iron cylinder at the heating bulb, for motor and arc-lamp circuits. The extra heat-absorbing capacity of the iron increases the time-lag of the indicator. It is suitable both for cc and ac circuits.

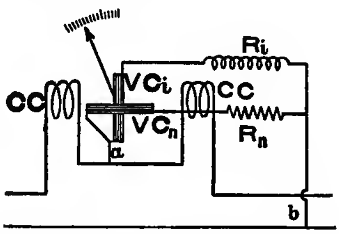
Fricker Maximum-demand Indicator.—This is also based on the thermal action of a current, and comprises a differential thermometer. This consists of a horizontal tube of uniform bore which terminates in two sealed bulbs, of which the one is horizontal and cylindrical, and the other vertical and spherical. The bore of the tube at the latter end is closed by a globule of mercury which acts as a valve. The tube is filled with hydrogen gas. On the passage of a current in the heating coil surrounding the cylindrical bulb, the gas expands past the valve, and into the vertical bulb. When cooling takes place, the gas contracts, and sucks the mercury globule along the bore of the tube. The ultimate position of the valve indicates the maximum current on a scale attached to the tube. The thermometer, with its heating coil, is enclosed in a box fitted with a water-jacketed chamber. The object of the latter is to cool the thermometer rapidly before a reading is taken. The thermometer is re-set to zero by withdrawing it from its case, holding it in a vertical position with the spherical bulb downwards, and slightly tapping it. The sluggishness of action of the instrument can be increased by increasing its heat-capacity. It is suitable both for ac and cc circuits.

Atkinson-Schattner Maximum-demand Indicator.—This is based on the electromagnetic principle of a current. It consists of a solenoidal ammeter having a soft-iron core. The core, which is circular in shape, is attached to a pivoted aluminium frame having an upper sector-shaped arm, to which is fixed, by its scale, a hermetically-sealed glass tube. The tube is bow-shaped, with a radial limb, and is filled with a viscous liquid, glycerine, for instance, and a series of steel balls. The balls are in the horizontal portion of the tube before the bend. On the passage of a current the iron core is sucked into the solenoid, and the tube, with its scale, is tilted. One or more balls slowly slide down the tube, and those which pass beyond the bend travel down the radial, lower limb of the tube, where they collect. The number of balls in this limb depends on the maximum angle of tilt, *i.e.* on the maximum current which has been flowing in the circuit to which the instrument is connected. The viscosity of the liquid used prevents temporary overloads from being recorded or transitory increases of current, and, by using a liquid of greater viscosity, the sluggishness can be increased. Duplicate scales, with the tubes attached, are provided, to prevent loss of time in re-setting the instrument. The scale gives the currents corresponding to the number of balls which pass round the bend into the radial limb, and the demand units for these currents at the supply pressure and the duration of the demand. The instrument is suitable both for ac and cc circuits. See also Handcock and Dykes Limit Indicator; Current Indicator; Merz Scale of Charges for Electricity; Contract-demand System. [H. G. S.]

Indicator, Merz. See Merz Scale of Charges for Electricity.

Indicator, Phase or Power-factor, an instrument for indicating the phase-relationship between current and pressure. There are two types.

1. A wattmeter type in which the phase-relation between the current and pressure fluxes is such that on a non-inductive load the torque is zero. For example, in a dynamometer wattmeter the pressure circuit is made highly inductive, and the instrument then indicates VA sin ϕ, instead of VA cos ϕ, that is, it will indicate the wattless component of the power, and is spoken of as an *idle-current wattmeter*, or *idle-current ammeter.*



Single-phase Power-factor Indicator of the Disk Type

2. A true phase indicator giving the pf or angle of lag or lead. The fig. shows a sp pf indicator of the disk type, the two pressure coils VC_n and VC_i are fixed at right angles to one another, and are connected through a non-inductive resistance R_n, and an inductive resistance R_i, respectively, across the mains. The coils CC are in series with the load. If the load is very inductive, the coil VC_n experiences little or no torque, and the system will set itself as shown in the fig. As the load becomes less inductive the torque on VC_i decreases, and on VC_n increases, so that the system takes up a fresh position for every angle of lag or lead. Such an instrument is, unfortunately, much affected by changes of frequency and wave-form, and slightly by changes of pressure. On polyphase systems the phase displacement need not be artificially produced, but can be that of the system itself, the indications are then independent of frequency, wave-form, and pressure. See Electrogoniometer. [K. E.]

Indicator, Pole or Polarity, an instrument used to indicate the direction of flow of an electric current. For switchboard use it is generally of the central-zero moving-coil pattern (see Ammeter), and for portable use of the pivoted magnetic-needle pattern. See also Detector, Magnetic; Electrolytic Detector.

Indicator, Speed. See Speed Indicator; Tachometer; Vibration Tachometer.

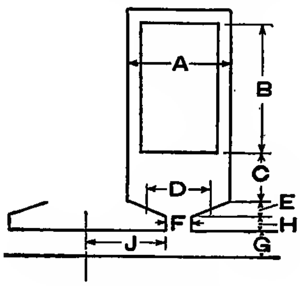
Indicator, Train-destination, in one form, consists of a board with the names of the stations arranged in a vertical column, alongside which is a semi-transparent sheet of glass. Behind the glass are stencilled numbers: 1, 2, 3, &c., in horizontal lines opposite each station name. The order of departure of trains is indicated by the temporary illumination of one of the numbers adjacent to the names of the first, second, third, &c., trains to leave. The numbers are changed after the departure of each train by switching off the incandescent lamps illuminating them, and switching on others.

Induced Electromotive Force. See Electromotive Force, Induced.

Inductance, the coefficient of self-induction, particularly used in practical problems, and expressed in henrys. The word is occasionally (and perhaps more fittingly) used for inductive reactance, expressed in ohms, being $2\pi \times$ frequency $\times$ coefficient of self-induction in henrys. The inductance of a circuit may be defined as the flux linkage when unit current flows in the circuit. It is also equal to the emf induced in the circuit when the current changes at unit rate. The dimension of inductance is a length, and hence the cgs unit of inductance is the cm. See Reactance; Induction, Self-; Henry. [F. W. C.]

Inductance, Ironless, a choking or inductance coil which has no iron in its magnetic circuit. Such coils are used as protective coils for transformers and generators where there is danger of damage to the windings, due to surges or potential waves coming in from the line or cable system. Such waves may be caused by sudden changes of current in the system, or, in the cases of overhead transmission lines, by lightning discharges. The use of iron in such coils is prohibitive owing to the exceedingly high frequency of the discharges or surges against which they have to afford protection, as the eddy currents induced in an iron core would reduce the inductance of the coil.

Inductance, Slot, that part of the inductance of a winding which is due to the leakage flux which flows across the slot. Taking the typical semi-closed slot shown in



Slot Inductance

the accompanying fig., the inductance in lines per amp per in is given approximately by

$$\frac{4\pi}{10} \times 2{\cdot}54 \times \left(\frac{B}{3A} + \frac{C}{A} + \frac{E}{D} + \frac{H}{F} + \frac{J}{2G}\right).$$

[H. W. T.]

Inductance Factor.—Though not so frequently used as pf, this term is very convenient as expressing the ratio of the idle or wattless current in a circuit to the total current flowing, or the ratio of the inductance of the circuit to its total impedance. If we are dealing with sine waves, the inductance factor is equal to the sine of the angle of lag, or the ratio of the inductance to the impedance of the circuit. See also IMPEDANCE FACTOR. [R. C.]

Induction, a word of various meaning introduced by Faraday so far as relates to electricity. It connotes, in general, phenomena produced in bodies by the influence of other bodies having no necessary material connection with them. Thus a body charged with electricity causes or 'induces' charges on neighbouring bodies. The process in this case is called *electrostatic induction.* A magnet induces magnetism in neighbouring masses of iron or other magnetic materials by the process of *magnetic induction.* A moving magnet induces electric currents in neighbouring conductors by the process of *electromagnetic induction.* In the two last instances the magnetic field due to a current may take the place of the magnet in inducing magnetism or other currents. A varying current in any circuit tends to set up currents in neighbouring circuits by the process of *mutual induction,* and, as a particular case, in its own circuit, by the process of *self-induction.* See INDUCTION, SELF-; INDUCTION, MUTUAL.

The word is also used to represent certain physical vectors having the nature of fluxes. Thus in electricity the induction through a surface is, per unit area, the product of the specific inductive capacity of the medium, and the component electric force normal to the surface. The integral of this, over a closed surface, can be shown to be equal to 4π times the electric charge included within the surface. The magnetic induction through a surface is, per unit area, the product of the magnetic permeability of the medium and the component magnetic force normal to the surface. Its integral over a closed surface is zero.

In this sense the word represents physical entities of great importance, which may be conceived in a sense as the strains due to the stresses of the corresponding forces.

[F. W. C.]

Induction, Current. See CURRENT INDUCTION.

Induction, Electromagnetic, the phenomenon of the production of electric currents by the variation of magnetic field. See INDUCTION.

The variation of the flux of magnetic induction through any circuit produces an emf round the circuit. The law governing this action, sometimes known as *Faraday's law of electromagnetic induction,* although not enunciated by Faraday, is as follows: The induced emf round any circuit is the rate of decrease of the total flux of magnetic induction through the circuit. It will be seen that when lines of induction are being added in a positive direction through a circuit, the induced emf is in the negative direction round the circuit. [F. W. C.]

Induction, Electrostatic, the action (or influence) of a charged conductor on the electrical state of another conductor, across a dielectric. See INDUCTION; LINE OF INDUCTION.

Induction, Line of. See LINE OF INDUCTION.

Induction, Magnetic, a physical vector of the nature of a flux, representing a certain state of polarisation in the medium near a magnet or source of mmf; that which is produced by mmf (which see). Magnetic induction may be defined as the value of the magnetic force within an infinitely thin, disk-shaped cavity in a medium—the axis of the disk being in the direction of the magnetic force. With this definition, it can be shown that magnetic induction satisfies conditions of the same type as are satisfied by the motion of a continuous incompressible fluid, *i.e.* the total flux entering any closed surface in space, is zero. See INDUCTION.

The flux of magnetic induction stands in the same relation to the magnetic circuit as does the electric current to the electric circuit (see CURRENT, ELECTRIC). It is, however, to be conceived as rather of the nature of a statical strain than a kinetic phenomenon.

As a measurable quantity, magnetic induction is synonymous with magnetic flux-density, and is usually expressed in cgs lines per sq cm, or decimal multiples thereof. See LINE OF INDUCTION. [F. W. C.]

Induction, Mutual, a particular case of electromagnetic induction in which the magnetic field producing an emf in a circuit is due to the current in a neighbouring circuit. The expression *mutual induction* is frequently used in the same sense as *coefficient of mutual induction*, which is a quantity pertaining to two electric circuits, and depending on their geometric forms, their relative positions, and the nature of the surrounding medium. It may be defined as the total magnetic flux threading one of the circuits, per unit current which flows in the other circuit, and which produces the flux. In this it must be understood that if any portion of the flux threads the circuit more than once, this portion must be added in as many times as it makes linkage.

The coefficient of mutual induction is of the same dimensions as length in the electromagnetic system of units. If the surrounding medium is non-magnetic, the coefficient of mutual induction is a constant for given circuits. In this case the coefficient is the same whichever circuit, in the above definition, the current is supposed to flow in—whence the name *mutual induction.* With iron in the path of the flux, however, the coefficient will vary with the current. The practical unit used in the measurement of mutual induction is the henry (which see). [F. W. C.]

Induction, Open-circuit, the magnetic induction in a transformer when the secondary is on open circuit or in an ac motor when it is carrying no load.

Induction, Resultant, the magnetic induction due to two or more mmf, *e.g.* the resultant induction in the air gap of a cc dynamo is partly due to the ats on the magnets, and partly to the armature ats, and is the resultant of the two inductions which would exist if first one and then the other of these circuits carried no current.

Induction, Self-, the property of an electric current by virtue of which it tends to resist any change of value. It is sometimes spoken of as *electromagnetic inertia*, and is analogous to the mechanical inertia of matter; a particular case of electromagnetic induction in which the magnetic field producing an emf in a circuit is that due to a current in the circuit itself.

The expression *self-induction* is frequently used in the same sense as *coefficient of self-induction*, which is a quantity pertaining to an electric circuit depending on its geometrical form and the nature of the surrounding medium. It may be defined as the total magnetic flux threading the circuit per unit current which flows in the circuit, and which produces the flux. In this it must be understood that if any portion of the flux threads the circuit more than once, this portion must be added in as many times as it makes linkage.

The coefficient of self-induction is of the same dimensions as length in the electromagnetic system of units. If the surrounding medium is non-magnetic, the coefficient of self-induction is a constant for a given circuit. With iron or other magnetic substance in the path of the flux, however, it varies with the current.

The coefficient of self-induction is sometimes called the *inductance*, or simply the *self-induction.* The practical unit used in its measurement is the henry. See HENRY; INDUCTANCE. [F. W. C.]

Induction, Unit of Self-. See HENRY; INDUCTION, SELF-.

Induction Ammeter. See AMMETER.

Induction Apparatus, Stationary. See STATIONARY INDUCTION APPARATUS.

Induction Coil. See COIL, INDUCTION.

Induction - coil Commutator. See COMMUTATOR.

Induction Density, a term used to express the intensity of magnetisation in a core of iron. It is expressed in lines or tubes of magnetic flux per sq cm of cross section, the section being reckoned at right angles to the direction of the flux. See MAGNETIC LINES OF FORCE; GAUSS.

Induction Meter. See under METERS FOR ALTERNATING ELECTRICITY.

Induction Motor. See MOTOR, INDUCTION; POLYPHASE MOTOR; SINGLE-PHASE MOTOR.

Induction-pattern Relay. See RELAY.

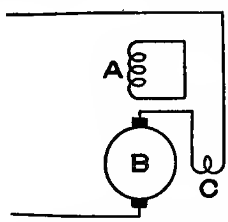
Induction Regulator. See REGULATOR, POTENTIAL.

Induction Voltmeter. See VOLTMETER.

Induction Wattmeter. See WATTMETER.

Inductive Capacity, Specific. See DIELECTRIC CONSTANT.

Inductive Compensation, a means of effecting compensation (which see) in which the current in the compensating coils is induced, the compensating circuit being completely insulated from the main circuit. An inductively-compensated series motor is illustrated diagrammatically in the fig.



Circuits of Inductively-compensated Series Motor

A, Compensating coil. B, Armature. C, Field coil.

See also SINGLE-PHASE MOTOR; COMPENSATION; CONDUCTIVE COMPENSATION.

Inductive Conductor for Telephone Lines.—Oliver Heaviside has shown that the addition of inductance improves the articulation on long telephone lines by reducing the distortion of the wave forms through loss of the upper harmonics. It is therefore now usual to insert inductive coils at intervals along trunk lines, or to use some other method of increasing the inductance.

Inductive Coupling. See COUPLING, INDUCTIVE.

Inductive Load, a current-consuming device which contains self-induction, or, more broadly, in which the current is out of phase with the ac pressure applied to its terminals, such as arc lamps, choking coils, induction motors (these cause the current to lag behind the pressure), and over-excited synchronous motors (these cause the current to lead in advance of the pressure). The pf of an inductive load is less than unity. (*N.B.* The broader definition given above includes the idea of capacity (condenser action), from which it must not be inferred that self-induction and capacity have the same meaning. Self-induction produces a lagging current; capacity produces a leading current.)

In paragraph 53 of the 1907 Standardisation Rules of the A.I.E.E. an *inductive load* is defined as—

'A load in which the current lags behind the voltage across the load. A load in which the current *leads* the voltage across the load is sometimes called an *anti-inductive load.*'

Inductive Relation.—Two circuits are said to be in inductive relation with one another when they are so placed that the variation of current in the one produces an emf in the other by the process of mutual induction (see INDUCTION, MUTUAL); the relation of two circuits specially arranged so as to have considerable mutual induction. The expression is particularly used in patent specifications and the like.

Inductive Resistance. See RESISTANCE, INDUCTIVE.

Inductive Voltage Drop. See FALL OF POTENTIAL.

Inductor Type of Alternator. See ALTERNATOR.

Indurated Fibre. See FIBRE.

Inefficiency (of Electric Lamps).—It is customary, but absolutely incorrect, to state the *efficiency* of electric lamps in wpcp. The consumption in wpcp is, of course, a measure of the *inefficiency.* The (luminous) efficiency is the ratio of the cp given out to the w consumed.

Inertia, Electromagnetic. See ELECTROMAGNETIC INERTIA.

Inferred-zero Method of Measurement. See ZERO, INFERRED OR SET UP.

Infinity Plug. See PLUG, INFINITY.

Infra-red Light. See LIGHT, INFRA-RED.

Inherent Regulation. See REGULATION; ALTERNATOR, PRESSURE REGULATION OF AN.

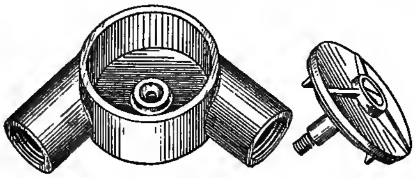
Inkless Recorder. See INSTRUMENT, RECORDING.

'In Phase'. See POWER FACTOR.

Input denotes the power which is absorbed by a motor, generator, or transformer. Such power may be electrical (measured in kw) or mechanical (measured in hp). The ratio of the *output* to the *input* is called the *efficiency.* The input is obviously equal to the output plus the losses.

Inspection Bend. See INSPECTION FITTING.

Inspection Fitting.—Couplings, T-pieces, bends, and other parts of an interior conduit system, provided with a removable cover so that the wiring may be readily



Inspection Bend

inspected, are termed *inspection fittings.* An *inspection bend* is shown in the fig.

Inspection Pit, a pit formed beneath the track of a railway or tramway by lowering the floor level between the rails, to provide ready access to the motors and other electrical equipment under the floor of a car, for inspection or repair.

Installation, Electric, a general term applicable to any arrangement of electrical apparatus such as plant for lighting, power, electrometallurgical or electromedical work, &c.

Installations, Low-tension.—These are defined by the V.D.E. (see Journ.I.E.E., vol. xli, p. 167) as—

'Installations in which the effective working pressure between any conductor and earth cannot exceed 250 volts. In the case of accumulators, the *charging* pressure is the determinant.'

See CURRENT, HIGH-PRESSURE.

Instrument, Electrical Measuring. See AMMETER; METER; VOLTMETER; WATTMETER; INDICATOR, PHASE OR POWER FACTOR; INSTRUMENT, RECORDING; INSTRUMENT, SWITCHBOARD MEASURING.

Instrument, Recording, also spoken of as a *registering* or *self-recording instrument,* or shortly, as a *recorder;* an instrument for recording, usually on a paper chart, the value at every instant of some variable quantity (*e.g.* volts, watts, temperature, &c.). In its simplest form it consists of a suitable measuring instrument whose pointer carries at its end a pen, resting lightly on a paper chart driven forward at a regular rate by clockwork. Thus a continuous line is traced and a permanent record obtained, showing at each instant the value of the quantity measured. Friction between pen and paper introduces considerable inaccuracy, which can be overcome in two ways: (1) In the *inkless recorder* the pen carries a steel tip which is pressed on to the paper through an inking ribbon at fixed intervals (*e.g.* every sec. or every fifth sec.), and is at other times free to take up its correct position. (2) The *spark recorder,* in which the record is made by a ht spark passing from the tip of the pointer through a prepared paper chart.

Instrument, Switchboard Measuring, a measuring instrument intended for switchboard — as distinguished from portable—use (see TESTING SET). Switchboard measuring instruments are usually fitted in round, sector, or edgewise metal cases, or sometimes, particularly for ht work, in cases of insulating material. Black and nickel (or copper) cast-iron cases have now largely superseded lacquered brass cases for this purpose. A *sector-shaped instrument* is one of roughly triangular shape, with its scale parallel to the switchboard, and the pointer moving in a plane also parallel to it. An *edgewise instrument* has a curved scale, either vertical or horizontal, and a pointer moving in a plane perpendicular to the switchboard. Edgewise instruments occupy very little space on the board, and can be packed-in, much like books on a bookshelf. They are, consequently, much used for feeder ammeters. (Ref. 'Industrial Electrical Measuring Instruments', Edgcumbe.)

Instrument Control, the force resisting the motion of the moving part of an instrument, and which has to be opposed by an equal and opposite force before equilibrium can be established. The commonest controlling forces are:—

1. GRAVITY CONTROL, in which a weight at the end of an arm attached to the pointer-spindle is raised from its position of rest, and exerts a gradually increasing force as the pointer deflects.

2. SPRING CONTROL, in which a spring, usually spiral in form, is wound up or unwound as the instrument deflects.

3. MAGNETIC CONTROL, in which either a pivoted magnetic needle tends to set itself parallel to a fixed magnetic field (usually that of the earth), or a piece of soft iron tends to set itself along the field of a permanent or electromagnet. In either case the controlling force gradually increases with the deflection. [K. E.]

Insulate, to separate an electric conductor from other conductors or from ground in such a way that no electric current can pass from one to the other. This is an ideal condition, never realised in practice, where it is sufficient to prevent any but relatively minute currents from passing.

Insulated Cable. See CABLE, PAPER-INSULATED; CABLE, RUBBER; CABLE, ASSOCIATION; CABLE, UNDERGROUND; VARNISHED-CAMBRIC CABLE; CABLE, FLEXIBLE.

Insulated Hanger, a hanger with ears by which it is supported, and sustaining an insulated bolt, from the lower end of which an ear (which see) is sustained. The ear, in turn, supports the trolley wire. A number of illustrations of various types of insulated hangers are given on p. 126 of vol. i of Wilson and Lydall's 'Electrical Traction'.

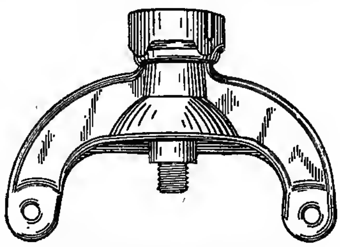


Fig. 1.—Double Pull-off Insulated Hanger

DOUBLE PULL-OFF.—In overhead work for electric traction this term signifies an insulated hanger for the trolley wire, so arranged that two pull-off wires can be attached and carried off in different directions. The trolley wire is attached below, and the pull-off wires are fastened to two holes in an arched metal piece, insulated from the part that grips the trolley wire. These insulators are used either as the main supports in span-wire construction, or to keep the overhead wire in place between

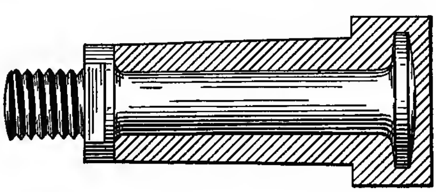


Fig. 2.—Insulated Bolt

the main supports on curves. Porcelain appears to be one of the most satisfactory materials for the insulating portion. A double pull-off insulated hanger is shown in fig. 1, and a section through its insulated bolt is shown in fig. 2.

SINGLE PULL-OFF, a type of insulated hanger used in the overhead construction of an electric tramway, and provided with a single lug, to which a wire is attached so as to pull the trolley wire into the correct position at a curve.

Insulated Middle-wire.—This term is applied to the middle wire of a three-wire system, when it is normally operated without any connection to ground. See THREE-WIRE SYSTEM.

Insulating Armature Conductors.—Armature conductors must be insulated both from each other and from the iron that surrounds them in the slot. For this purpose they are enclosed in tubes or wrappings whose thickness and composition depend chiefly on the working pressure of the machine. The most commonly used materials are treated paper, treated cambric, mica, and linen or cotton tapes, generally re-enforced by impregnation with some good insulating varnish. Information on the properties and uses of the various materials will be found under their respective headings.

Insulating Boots. See Home Office definitions under INSULATING STAND.

Insulating Bush. See BUSH, INSULATING.

Insulating Compound, a general term applied to a mixture of materials, designed to give the insulating and physical properties required for a particular purpose. The ingredients of an insulating compound may not actually chemically combine, but their mixture with each other is so thorough that the compound possesses different properties from those of any of the ingredients. Insulating compounds may be roughly divided into three classes, viz.:—

1. Impregnating Compounds.
2. Waterproofing Compounds.
3. Joint-box Compounds.

1. IMPREGNATING COMPOUNDS are used for the treatment of fibrous materials. They increase the insulating properties of the fibrous materials, render them moisture-proof and able to withstand the effect of heat with less rapid deterioration. The choice of an impregnating compound will be determined by the nature of the material it is to impregnate and the conditions to be withstood. An impregnating compound should have the following characteristics: (1) It should be moisture-proof. (2) Melting-point must not be too high. (3) Good insulating properties. (4) Withstand heat and vibration without crumbling. (5) Withstand warm lubricating mineral oil without

disintegration. See also Heat-dissipating Impregnating Materials; Impregnated Insulating Materials.

2. Waterproofing Compound, a general term applied to a material or mixture of materials which is 'water-repellent'. The coil or apparatus is generally insulated, and then given an impregnation with a waterproofing compound which thoroughly seals all crevices and produces a 'water-repellent' covering.

3. Joint-box Compound. — Compounds are used for filling joint-boxes on underground networks. For this purpose the compound should be 'water-repellent', but not too hard. [H. D. S.]

Insulating Coupling.—It is sometimes desired to couple two lengths of shafting together, as in a motor-generator, and at the same time to prevent the passage of electricity from one to the other. In such a case an insulating coupling is used. The types of coupling most easily adapted to this purpose are the *band coupling* (which see), the *claw coupling* or *claw clutch* (see Clutch), and *Oldham's coupling* (which see). See also Plate Coupling; Coupling, Flexible; Coupling, Shaft.

Insulating Gloves. See Home Office definitions under Insulating Stand.

Insulating Materials, Energy Losses in.—When insulating materials are subjected to dielectric stress, as for instance when employed in electrical apparatus, they are the seat of certain energy losses which appear as heat in the body of the material. Investigation has shown that these losses are due to two distinct effects, which in practice are exceedingly difficult to separate. The first of these causes is simply the I^2R loss, due to leakage through and over the insulation (see Dielectric Resistance). This forms probably the major part of all dielectric losses, and indeed the only part in cc apparatus. Under alternating pressure, however, a true *dielectric hysteresis* appears, which is analogous to the well-known magnetic hysteresis. A certain amount of energy is needed to establish a given difference of potential across an insulating body. This energy is employed in work done against the dielectric strain, which appears to consist of some molecular or ionic rearrangement. When the pd is removed, and the dielectric allowed to 'discharge', most of this energy is given out again, but not quite all. The small amount retained, possibly due to molecular friction of some kind, is the *dielectric hysteresis loss.* Under an alternating potential this loss appears twice every cycle, so that the loss in w increases with the frequency. It is not definitely known whether the loss is proportional to the frequency, but it appears that it increases more rapidly at the higher frequencies. There is no doubt, however, that the heat imparted to the insulating body by reason of these losses is a prime cause of *insulation breakdown*, and it may be that the loss increases greatly with the temperature (see 'Insulation Breakdown' under Insulation). (Ref. 'Theory and Calculation of Alternating Current Phenomena', 2nd ed., p. 145, Steinmetz; Humann, Elec., vol. lviii, p. 170; Monasch, Elec., vol. lix, pp. 416 *et seq.*) [J. S. S. C.]

Insulating Oil. See Oil, Insulating.

Insulating Qualities.—For the purposes of electrical engineering, the qualities desirable in a good insulating material are:—

1. Permanence.
2. High power of resisting breakdown.
3. Mechanical strength.
4. Fairly high dielectric or insulation resistance.
5. Special qualities for the use to which the material is to be put.

Permanence is the most important quality, and is the one least easily attained. The power of resisting breakdown is a complex quality, for it is not solely dependent on mere puncturing pressure, but also on mechanical goodness, and, to a certain extent, on insulation resistance. It cannot be easily determined by a simple laboratory test, but must be found by experience of actual service conditions. Some account of the insulating qualities of various materials will be found under their respective headings. See 'Insulation Breakdown' under Insulation; Dielectric Resistance.

Insulating Screen. See Home Office definitions under Insulating Stand.

Insulating Stand means a floor, platform, stand, or mat ...	of such size, quality, and construction according to the circumstances of the use thereof, that a person is thereby adequately protected from danger.—
Insulating Screen means a screen ...	
Insulating Boots means boots	
Insulating Gloves means gloves ...	

(From definitions accompanying Home

Office, 1908, Regulations for Electricity in Factories and Workshops.)

Insulating Stool, a stool made with legs of glass or other insulating material, so that bodies placed on it are completely insulated from the ground. Insulating stools are generally used either to insulate a complete measuring instrument, when used for tests at high pressures, or for an operator to stand upon in order that he may safely handle, or work at, live conductors.

Insulating Table, a table whose legs are formed wholly or partly of insulating material (glass, porcelain, &c.), so that any apparatus placed on it is efficiently insulated from the ground.

Insulating Tube.—Insulating tubes of various materials are used for a number of purposes in electrical engineering. Some of the many forms will be found described under the headings SLOT INSULATING TUBE; 'Wall-entrance Insulator' under INSULATOR; VARNISHED-CAMBRIC TUBE; PERTINAX; MICANITE; MICARTA.

Insulating Varnishes.—These are employed for impregnating fibrous materials, to improve their insulating properties and to render them moisture-proof. No one varnish embodies all the essential properties requisite to meet the various necessities arising in practice, and discretion is needed to select one that will prove permanent for the purpose in view.

An insulating varnish should dry with a smooth, hard surface, giving a tough, uniform coat that will be moisture-proof, and will withstand the action of hot oil; it should have high dielectric strength, which must remain permanent; it should be acid-free, and should not become brittle with continued heating. From the nature of the materials employed in their manufacture, no varnish remains permanent for all time; but one that will withstand continuous baking for 300 hours at a temperature of 75° C., without becoming unduly brittle, will age well.

Experience will determine the best consistency and most economical method of using a varnish. Insulating varnishes may be divided into two classes, viz.:—

1. Baking Varnishes.
2. Air-drying Varnishes.

1. BAKING VARNISHES.—These are tougher and of a more durable character than are air-drying varnishes; their manufacture is a trade in itself. They usually consist of drying oil, resin, and 'drier', thinned to a suitable consistency with a volatile solvent. In the process of drying, the solvent is evaporated, and the oil absorbs oxygen from the air, forming with the resin a hard lustrous coat. The 'drier' is a material added to hasten the absorption of oxygen.

The material to be treated may be vacuum-impregnated, or it may be thoroughly dried at not too high a temperature, and immersed whilst warm for a sufficient time to become impregnated. On removal, the superfluous varnish is allowed to drain off, and the coil is dried either in a vacuum oven or in a baking oven, at a temperature of 75° to 90° C.; if a vacuum oven is employed, it will be necessary to frequently admit fresh air to allow of the absorption of oxygen. Two or more coats are usually given, the varnish being baked after each coat.

2. AIR-DRYING VARNISHES.—These comprise both oil and spirit varnishes, the former being specially manufactured to air-dry. The insulating properties of air-drying varnishes are lower than those of baking varnishes. They are not so moisture-proof, and will not so well withstand the action of hot oil. See also OIL AND SPIRIT VARNISHES; CORE-PLATE VARNISHES; ELASTIC INSULATING VARNISHES. (Ref. 'The Insulation of Electric Machines', chap. viii, Turner and Hobart.)

Standard and *Sterling* insulating varnishes are trade names given to lines of baking and air-drying insulating varnishes designed to meet the varied requirements arising in practice. These are only two of many brands of excellent varnishes now on the market. [H. D. S.]

Insulation, (1) the act of insulating; (2) anything that is used to insulate electric conductors from one another or from ground.

INSULATION OF LAMINATIONS.—Iron laminations for electrical purposes are insulated from each other, to prevent heating by induced eddy currents of low emf.

For this purpose, a material is required capable of being applied in very thin layers. It should have high resistance, and should not become brittle or disintegrate with heat and vibration; for oil-cooled apparatus it should be insoluble in warm mineral oil. Paper, varnish, insuline, lacquer, and graphite are the materials employed for this purpose, and are dealt with under their respective names. (Ref. 'The Insulation of Electric Machines', chap. xviii, Turner and Hobart.) See CORE-PLATE VARNISHES; JAPANESE PAPER; DISCUM VARNISH; GRAPHITE; FRENCH CHALK FOR ASSEMBLING CORE PLATES.

INSULATION OF MAGNET WIRE.—The term *magnet wire* is applied to copper wire, lightly insulated with cotton or silk, or else enamelled. There are three types of cotton and silk covering, viz.:—

1. A spirally lapped covering.
2 A braided covering.
3. A covering that is spun around the wire.

The latter is a recent invention, and is as yet only used for cotton covering on wires of small diameter. The braided covering is most generally adopted for square wires, being mechanically stronger than a spirally lapped covering. See also WIRE, COTTON-COVERED; WIRE, SILK-COVERED; WIRE, ENAMEL-INSULATED; WIRE, MAGNET; ENAMELLED COPPER WIRE. (Ref. 'Conductors for Electrical Distribution', F. A. C. Perrine; 'The Insulation of Electric Machines', Turner and Hobart.)

SEGMENT INSULATION, the insulation (usually of carefully chosen mica) which separates one commutator bar from the next.

INSULATION BREAKDOWN.—When a piece of any insulating material is placed between two conducting bodies (electrodes), and these latter have a pressure applied between them, then if the pressure is continuously raised, a discharge eventually passes between the electrodes. This discharge may either pass over the insulating body through the air or other medium in which the experiment is conducted, or it may pass through the body itself. In the latter case the insulation is said to be broken down, and a hole with more or less charred edges will be found if the material be solid. This is called *puncturing of the insulation.* The discharge is called a *disruptive discharge,* since it breaks its way through the material.

The breakdown appears to be due in every case to one or more of three causes.

1. A small leakage current passes through the most perfect of actual insulating materials. At any place where this current is stronger than elsewhere, for any reason, local heating is set up, followed often by chemical or physical changes which allow more and more current to pass, until finally the heat is sufficient to burn a hole in the material. In the case of an alternating pressure the heating is augmented by dielectric hysteresis pure and simple, but probably the current heating is generally of greater magnitude.

2. The dielectric strain is apparently accompanied by actual physical forces which may cause puncture, but in what way is not definitely known.

3. The potential fall through the dielectric is the cause of ionisation. This allows a small current to flow, which is progressively followed by more ionisation and the development of heat, breakdown ultimately resulting. It may be that the second and third causes are in reality one and the same.

In the case of gases, the third case is doubtless the full explanation, and it is most probably so in the case of liquid dielectrics of high insulating power. For solid dielectrics the first cause mentioned appears to be the determining factor, except in the case of so-called instantaneous breakdowns, when the second may be the true explanation. It is, however, at present impossible to say whether any breakdown takes place absolutely instantaneously. See also GRADING OF INSULATION; DIELECTRIC STRENGTH; 'Insulation of Cables' under CABLE, UNDERGROUND; COMMUTATOR INSULATION, EFFECT OF OIL ON.

Insulation, Heat. See 'Heat Insulation' under CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Insulation, Lava.—This is the mineral talc ($Mg_3H_2Si_4O_{12}$) baked at a temperature of about 1100° C. to a condition of extreme hardness. In its natural condition it can be turned, threaded, or sawn to any desired shape, and, after baking, will be more accurate than porcelain to required dimensions. It is acid- and alkali-proof, quite unaffected by any reasonable temperature, and has a dielectric strength of some 500 volts per tenth of a mm thickness; it allows slight surface leakage, but does not absorb moisture; it finds a large use for arc-lamp and rheostat bushings. See LAVITE INSULATING MATERIAL.

Insulation, Magnetic, an air gap in a magnetic circuit. No good magnetic insulator is known, and the term *insulator* applies only relatively.

Insulation Resistance (see also DIELECTRIC RESISTANCE).—The following definition and related notes constitute paragraphs 210 to 213 of the 1907 Standardisation Rules of the A.I.E.E.:—

'*Insulation resistance* is the ohmic resistance offered by an insulating coating, cover, material, or support to an impressed voltage tending to produce a leakage of current through the same.

'*Ohmic Resistance* and *Dielectric Strength.*—The ohmic resistance of the insulation is of secondary importance only, as compared with the dielectric strength or resistance to ruptnre by high voltage. Since the ohmic resistance of the insulation can be very greatly increased by baking, whereas the dielectric strength is liable to be weakened thereby, it is preferable to specify a high dielectric strength rather than a high insulation resistance. The high-voltage test for dielectric strength should always be applied.

'*Recommended Value of Resistance.*—The insulation resistance of complete apparatus should be such that the rated voltage of the apparatus will not send more than $\frac{1}{1,000,000}$ of the rated load current at the rated terminal voltage through the insulation. Where the value found in this way exceeds 1 megohm it is usually sufficient.

'*Insulation resistance tests* should, if possible, be made at the pressure for which the apparatus is designed.'

Insulation-testing Transformer. See TRANSFORMER, INSULATION-TESTING.

Insulation Tests. See TESTING INSULATION; TESTING ARMATURES; TESTING TRANSFORMERS; TESTING JOINTS; TESTING FOR FAULTS; OHMMETER.

Insulativity, a term employed to denote the property of substances, whether in the solid, liquid, or gaseous state, of offering such high resistance that they may be used as 'non-conductors'. Such substances are called *insulators*.

The term is employed by Russell, and is defined on p. 49 of his 'Theory of Electric Cables and Networks' as 'the resistance of a cm cube of the material to a flow of electric current at right angles to two opposite faces; it is thus the same as the volume resistivity'. Russell points out that the insulativity is usually measured in megohms, while the resistivity is usually measured in microhms.

Insulator.—The term *insulator* is used in two senses: (1) an insulating substance or medium. No known insulator has the power of absolutely preventing the passage of electric currents between conductors, but many have sufficient insulating power for practical purposes. The properties to be desired in a good insulating material will be found under the heading of INSULATING QUALITIES. (2) A specially formed piece of some insulating material, such as glass, porcelain, ambroin, &c., used to insulate conductors at their points of support. Examples of this use of the word are LINE INSULATOR, PETTICOAT INSULATOR, STRAIN INSULATOR (defined in this article).

MOULDED INSULATORS.—Under this term are included a number of moulded compositions and hard-rubber substitutes sold under various trade names. They are manufactured by the mixture of organic and inorganic materials, moulded under pressure to the desired shape, the ingredients and method of manufacture being varied to produce a material to suit the requirements. The physical properties required will to a large extent determine the choice of a moulded material, for, except in the case of arc-proof compositions, the dielectric strength and insulation resistance are generally high. Few compositions are tough enough to be threaded, and where a thread is desired it usually has to be moulded. The quality of a composition can be judged by the extent to which it fulfils the following conditions:—

1. Moisture-proof.
2. Unaffected by warm mineral oil.
3. High softening temperature.
4. Not readily inflammable.
5. Unaffected by dilute acids and alkalis.
6. Hard and tough.
7. Should not lose its finish or become brittle with age.

SECTION INSULATOR.—In overhead trolley construction it is necessary to divide the con-

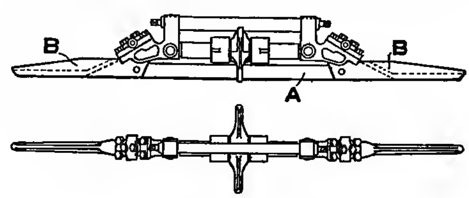


Fig. 1.—Section Insulator

A, Insulating material. B, Conducting material.

ductor into electrically separate lengths. In Britain the Board of Trade regulations provide that these lengths shall not exceed half a mile. For this division of the conductor *section insulators* are used, which must be constructed so as (1) to grip firmly the two ends of the trolley wires, (2) to insulate them one from the other, even when one is grounded, and (3) to present a smooth path by which the trolley wheel may pass from one wire to the other without shock. This last is generally effected by inserting a narrow piece of hard wood between the two metal parts which grip the wires. In fig. 1 A is the insulating piece, and the parts B are of conducting materials.

Third-rail Insulator.—The insulators used to support the conducting rails for electric railways are almost universally made of porcelain or earthenware. They are usually supported by an iron pin fastened to an extension of the sleeper. The special features to be observed in their design are great mechanical strength; good insulating quality in spite of rain, snow, and dirt; and ease of replacement when damaged. The rail safety-guards are carried on an iron cap which rests on the top of the insulator proper. A standard design of third-rail insulator, not however of the precise type above described, is shown in fig. 2.

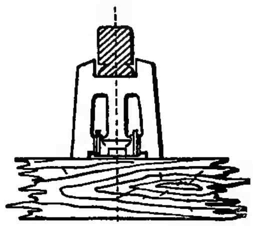


Fig. 2.—Third-rail Insulator

Strain Insulator, an insulator for use on overhead circuits, and capable of withstanding the tension of a wire strained up to a pole, &c. The majority of strain insulators are used to fasten a live overhead wire to a grounded wire attached to a post at curves or termini of a line. Thus strain insulators are used to a large extent on overhead trolley circuits, more particularly at anchorages, or with frogs and crossings, or with span wire. The *Brooklyn strain insulator*, shown in fig. 3, and other insulators of this type, allow of screw adjustment to tighten the wires attached to them (see also Turnbuckle, Insulated). Both bronze and iron are used for the metal parts, the former having the advantage that it does not rust so rapidly as the latter. Strain insulators are also made *globe shape*, in which case they are not adjustable. A special insulating material is used, and in the best construction this is used in conjunction with mica under compression between the opposite metal portions. (Ref. 'Modern Electric Practice', vol. iv; 'Electrical Traction', Wilson and Lydall.)

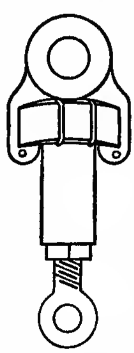


Fig. 3.—Brooklyn Strain Insulator

Globe Strain Insulator, a favourite form of strain insulator used in overhead trolley work for tramways. The iron parts are two similar links, each consisting of a short straight portion with a ring formed at its end (see fig. 4). These are linked together, and around the two rings which pass through one another a globe of insulating material is moulded in such a way that they are separated at all points by the insulating material. The rings, which project at either side, are used for attaching the span wires. When the stress comes on the insulator, the moulded insulating material is subjected to compressive stress only, against which it is much stronger than for either tension or shear. A globe strain insulator thus transmits the tensile stress, while electrically interrupting the wire or cable in the course of which it is inserted.

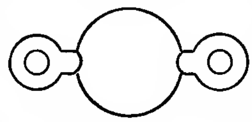


Fig. 4.—Globe Strain Insulator

Terminal Insulator, an insulator used at the end of an overhead line—whether a trolley wire, transmission line, or telegraph circuit, to perform the double function of insulating the line, and of transferring its tension to the wire which is fastened to the terminal pole. A strain insulator of some form must be used for this work.

Line Insulator, any insulator used for insulating an overhead line from ground. For telegraph and telephone purposes line insulators are practically always small porcelain insulators of the petticoat type. For power circuits larger examples of the same class are used, while for very high voltages the 'link' insulator (see below) is now beginning to be employed.

Wall-entrance Insulator.—This is an insulator used where ht overhead lines are brought down into a building through the wall. It generally consists of a tube, often corrugated around its outside surface, or with smaller tubes inside it, set in the wall with a downward slope to the outside. A type of wall-entrance insulator is shown in fig. 5. (Ref. 'High-tension Outlets', Proc. A.I.E.E., vol. xxv, p. 865, Alvin Meyers.)

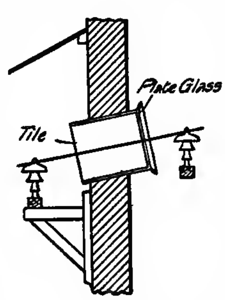


Fig. 5.—Wall-entrance Insulator

Transposition Insulator, a special type of insulator used for the transposition of line or telephone wires. It is generally made so that the two wires can be carried on the same insulator, and so that each is efficiently insulated both from ground and from the other wire. By its means, wires which have been running side by side can be brought vertically, one above the other, at one pole, and the cross-over can be effected in this manner. See TRANSPOSITION OF CONDUCTORS IN TRANSMISSION SYSTEM.

SUSPENSION INSULATOR. See 'Link Insulator' below.

PETTICOAT INSULATOR.—The commonest form of insulator for line work is one which is supported by a central pin, and is provided with one or more *petticoats* (see fig. 6). These are thin concentric walls formed in the material of the insulator, and designed to give increased surface distance from the line to the pin, and to shed rain. The ordinary telegraph or telephone insulator is a porcelain petticoat insulator. For high-voltage work, and especially with glass insulators, the outer petticoat is often formed with 'teats' projecting downwards. These allow the moisture to drip away easily, and thus prevent it from creeping up inside the petticoat. A petticoat insulator is sometimes termed a *mushroom insulator*.

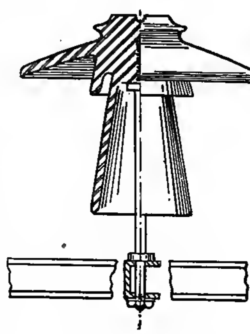


Fig. 6.—Petticoat Insulator

HIGH-VOLTAGE INSULATOR, an insulator for high-pressure lines. A 44,000-volt petticoat insulator is shown in fig. 7. Until recently the only kind in common use has been the petticoat, which, as the working pressure became higher, has been provided with larger, deeper, and more numerous petticoats. Other types have now been evolved, notably the 'link' insulator (see below), but the petticoat insulator is still the type most generally employed.

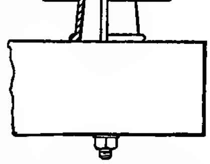


Fig. 7.—High-voltage Insulator

LINK INSULATOR, a type of insulator recently introduced for extra-high pressure work. It is developed both as a line insulator and as a strain insulator. It will be best understood from the illustration (fig. 8), which is taken from a paper by Hewlett in Proc.A.I.E.E. for June, 1907. It has the

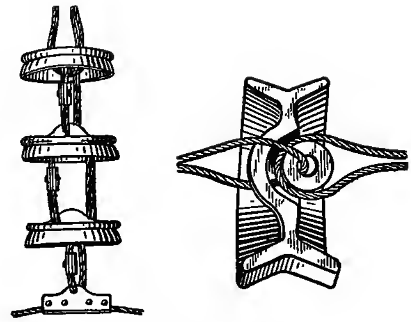


Fig. 8.—Link Insulator

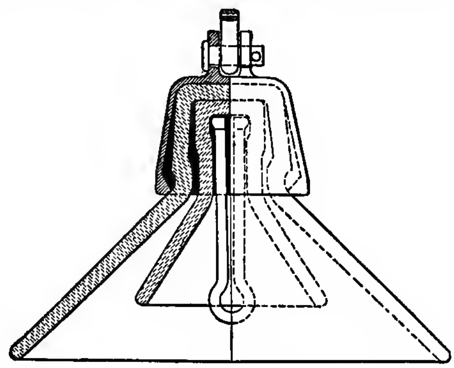


Fig. 9.—Link Insulator

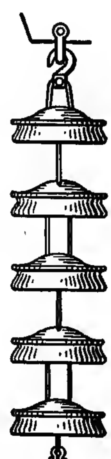


Fig. 10.—Link Insulators in Series

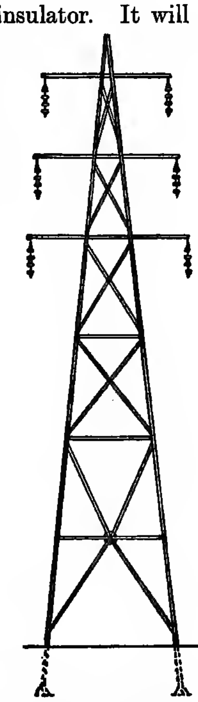
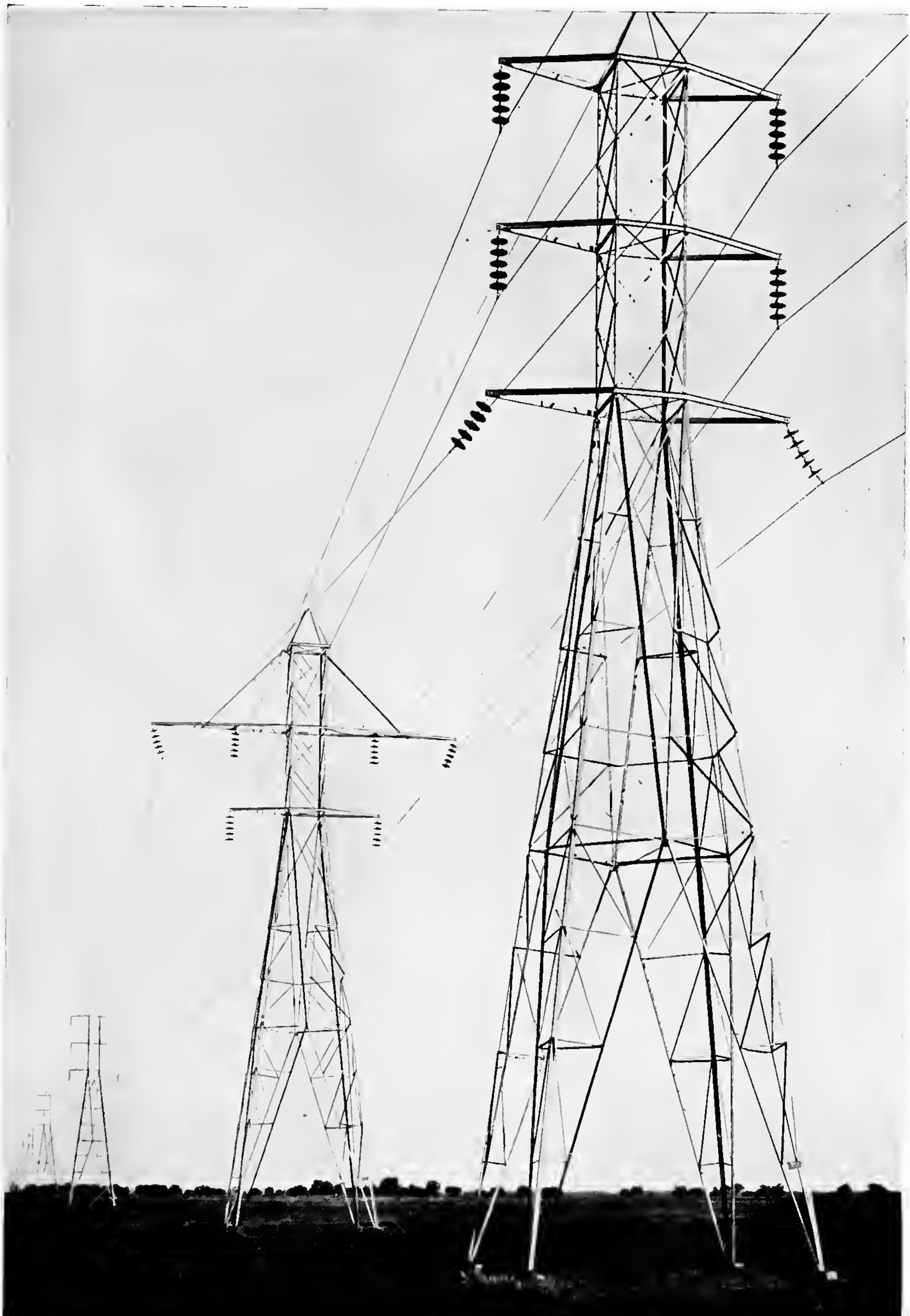


Fig. 11.—Transmission Tower supporting Link Insulators



OVERHEAD LINE FOR 100,000 VOLTS, SHOWING TRANSPOSING TOWERS

(Reproduced by permission from Messrs. Marchant and Watson's paper on "Recent Developments in the Transmission of Electrical Energy", Proc. I.E.E., Vol. xliv, p. 423)

[*To face p. 278.*

following great advantages: (1) The porcelain is subjected to compressive stresses only; (2) several insulators can be used in series for higher pressures; (3) if the porcelain breaks, the line does not fall; (4) it presents a surface well adapted to maintain good insulation in all states of the weather. A link type of insulator is sometimes termed a *suspension insulator*. A single link of an alternative type of link insulator is shown in fig. 9. In fig. 10 are shown five link insulators in series, and in fig. 11 is indicated a transmission tower supporting the insulators. See Trans. A.I.E.E., vol. xxvi, pp. 1259 and 1263.

SHACKLE INSULATOR, an insulator employed in overhead lines where there are sharp angles as well as where the line terminates. A shackle insulator differs from the ordinary petticoat insulator (sometimes called *mushroom insulator*, and sometimes *straight-line insulator* because it is used for the straight parts of a transmission line) in being designed for transverse stresses. One type of shackle insulator is illustrated in fig. 12, and it should be compared with the ordinary petticoat or 'mushroom' insulator already illustrated in figs. 6 and 7.

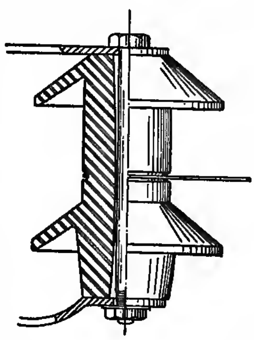


Fig. 12.—Shackle Insulator

TOP-GROOVE INSULATOR, an insulator designed to support the conductor on its upper surface, as shown in fig. 13.

ACCUMULATOR INSULATOR.—In order to prevent leakage, each cell in a battery of accumulators is placed upon four, and in the case of large cells, six insulators, consisting of two saucer-like pieces of glass, standing one on the other, as shown in fig. 14. The lower piece contains a small quantity of heavy oil to increase its insulating properties. In cases where one pole of the system is connected to earth, such as a tramway system, the bearers on which the cells rest are themselves mounted on insulators, with the same object.

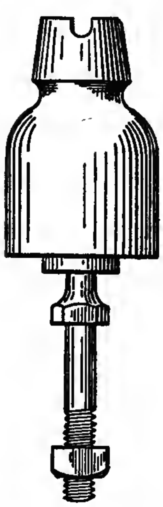


Fig. 13.—Top-groove Insulator

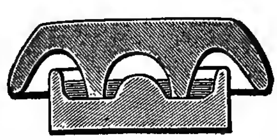


Fig. 14.—Accumulator Insulator

OIL INSULATOR.—This is a type of porcelain or glass insulator in which the leakage path is interrupted by an oil surface. The oil is contained in a circular trough generally formed in one of the petticoats of the insulator.

FLOOR INSULATOR, an insulating tube, commonly of porcelain, used to protect conductors where they pass through floors, for instance between transformer basements and switchboard galleries.

FLUID INSULATOR.—All fluid insulators of any practical importance are either organic liquids or gases. Liquids are used for insulating purposes very largely in transformers and in ht oil switches. All gases are good insulators when in thick layers, as their insulation resistance is extremely high unless they are excessively ionised, while their breakdown pressure is low at normal pressures. See also COMPRESSED GAS AS AN INSULATOR; INSULATED HANGER; DIELECTRIC STRENGTH; OIL INSULATION.

Insulator Cap, a cap of metal, often malleable iron, fastened to the top of a line insulator, to distribute over the porcelain the stress of the wire and fastening. With long spans and taut wires, a plain fastening would produce on the insulator a stress which would be too much concentrated on the points of contact.

Insulator Pin.—Most line insulators are arranged to be supported by a central pin fitting tightly in a special hole formed in the body of the insulator itself. These pins are generally made either of *wood* or of *wrought iron*. In the latter case, they are usually fastened by some cement, such as glycerine and litharge. The relative merits of the two kinds of pins have been the subject of some discussion, and the question cannot be regarded as settled.

CHARRING OF INSULATOR PIN.—When wooden pins are used for supporting the insulators, on a ht transmission line, they are occasionally destroyed by charring. This occurs chiefly by reason of the leakage that takes place over the insulators in wet weather, throwing a voltage stress on the pin itself. If the wood is at all conductive, it will then be charred by the passage of the leakage current. The remedies are (1) to so arrange the petticoats of the insulator as to minimize leakage even under the worst conditions, and (2) to use pins either of thoroughly treated and seasoned wood, or of some other material altogether. See CARBONISATION; 'Insulator Pins' under LINE POLES.

Insulator Stand for Accumulators, a block of glazed porcelain, usually circular in shape, for carrying the wooden stands on which the battery rests, and so preventing any leakage to earth. See fig. 14 under INSULATOR.

Insuline, the trade name of a material for the insulation of laminations. It gives a hard, tough, thin coat insoluble in hot mineral oil. See CORE-PLATE VARNISHES; DISCUM VARNISH; 'Insulation of Laminations' under INSULATION.

Insullac, the trade name of a transparent mica-sticking varnish, which the manufacturers state may be used for either built-up mica or mica-paper manufacture. See MICA-STICKING VARNISH; MICANITE; MEGOHMIT.

Integrating Mechanism, the registering part of a meter, which consists of a train of wheels and pinions gearing with one another, and actuating index hands over graduated circles on the front of a dial, as in the ordinary dial register, or a series of number wheels, or drums, the figures on which appear in line through slots in the dial face, as in the cyclometer counter. The first motion wheel of the train is usually driven direct through a worm, or pinion, on the meter spindle. The integrating mechanism is invariably arranged so that the dial-reading gives the energy consumption direct in terms of the unit of electrical energy (kelvin or kw hr or BTU) without a multiplier, or constant. See CYCLOMETER COUNTER; DIAL REGISTER.

Integrating Meter. See METER, HOUSE-SERVICE.

Integrating Photometer. See PHOTOMETER, INTEGRATING.

Integrating Wattmeter. See METER, ENERGY.

Intensity of a Magnetic Field, strength of a magnetic field; the number of lines of force per cm existing in a section taken at right angles to the direction of the field; the induction density in the field. See INTENSITY OF MAGNETISATION; GAUSS; MAXWELL.

Intensity of Field. See INTENSITY OF A MAGNETIC FIELD.

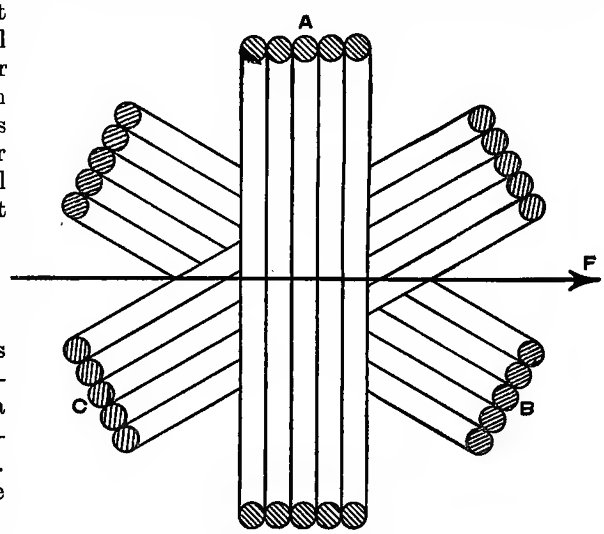
Intensity of Magnetisation.—1. Flux density from which is deducted the 'air-lines' (which are numerically equal to the magnetic field existing at the point under consideration).

In scientific work the intensity of magnetisation is properly expressed as $\frac{1}{4\pi}$ times the above amount. [D. K. M.]

2. A physical quantity devised to represent the condition of a magnetised substance with respect to its magnetisation. A magnetised substance being an aggregation of magnetised parts, if a cylindrical element be taken lying in the direction of magnetisation at any point, the intensity of magnetisation at that point is the strength of a pole of this elementary magnet per unit area of pole face. It will be seen that intensity of magnetisation is a vector. [F. W. C.]

Intensity of Pressure. See PRESSURE, INTENSITY OF.

Interaction of Phases, a term denoting the mutual inductive effects between the phase windings in generators or transformers. In the two-phase winding of a generator or motor, where the coils of two circuits are in quadrature, there is no direct interaction, *i.e.* a current in one will not induce an emf in the other. But in three-phase machines



Interaction of Phases

mutual induction exists, and a current flowing in one phase induces emf in the other two.

In the fig., A, B, and C represent sections of three circular coils placed at 120°. Let an alternating current be passed through A alone. Then a certain flux F will be produced which will induce a voltage in A. Let now equal currents flow through B and C, the whole being fed from a three-phase source. Due to the angles at which the coils are placed, the combined inductive effects of B and C on A will be to induce an additional voltage in the latter in the same phase as, and equal to half that existing before, so that the total voltage now induced in A is 1·5 times greater than before. Hence the magnetising effect of the three phases is equal to 1·5 times that of one phase alone. [R. C.]

Interconnecting Feeder. See FEEDER.

Interference, Armature. See ARMATURE INTERFERENCE.

Interferric Space. See CLEARANCE OR CLEARANCE SPACE; AIR GAP.

Interior Conduit. See CONDUIT, INTERIOR.

Interlocked Circuit Breaker. See CIRCUIT BREAKER.

Interlocking Commutator Segments. See COMMUTATOR SEGMENT.

Interlocking Device. See LOCKING DEVICE.

Interlocking Electromagnet, an electromagnet the action of whose plunger or armature is interlocked with some other mechanism.

Interlocking Signal. See SIGNAL, INTERLOCKING.

Interlocking Switch. See SWITCH, INTERLOCKING.

Intermittent Current. See CURRENT, INTERMITTENT.

Intermittent Earth. See EARTH.

Intermittent Integration. See METER, INTERMITTENT REGISTERING.

Intermittent Rating. See RATING, INTERMITTENT.

Intermittent Registering Meter. See METER, INTERMITTENT REGISTERING.

Internal Drop. See FALL OF POTENTIAL.

Internal-field Machine. See 'Revolving-field Type of Alternator' under ALTERNATOR.

Internal Insulating Bush. See BUSH, INSULATING.

Internal Latent Heat. See STEAM.

Internal Lightning Phenomena. See STATIC DISTURBANCES.

Internal Resistance of an Accumulator, the resistance measured across the terminals of an accumulator or one cell of the accumulator. See ACCUMULATOR.

Internal Resistance of Armature.— In commutator machines the internal resistance of the armature is the resistance of the windings from the points where the brushes of one polarity bear on the commutator to the points where the brushes of the other polarity bear on the commutator. In ac machines without commutators it is sometimes taken as the resistance between slip rings when the armature is the rotor, or between terminals when the armature is the stator. In polyphase windings it is preferable to consider separately the *internal resistance of each phase* of the armature winding. See also ARMATURE RESISTANCE.

Internal Voltage, the emf generated in the winding of the armature of a dynamo without any deduction for the drop occasioned by copper resistance or inductance. The internal voltage is equal to the terminal voltage plus the internal volts in the winding.

International Ampere. See AMPERE.

International Coulomb. See COULOMB.

International Ohm. See OHM.

International Volt. See VOLT.

International Watt denotes the international unit of electrical power. See WATT.

Interpolar Conductor, a conductor situated in the interpolar space. See POLAR FACE.

Interpolar Space. See POLAR FACE.

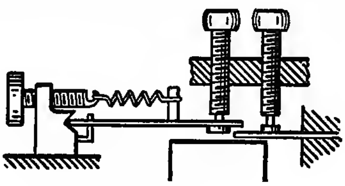
Interpole Dynamo or Motor, a dynamo or motor with interpoles. See INTERPOLES.

Interpoles, auxiliary poles magnetised by series coils and placed between the main poles of a cc generator or motor in such a way as to produce an auxiliary flux at the point where the armature coils are short-circuited by the brush, this field being in such a direction as will assist the reversal of current in the short-circuited coils. The excitation being produced by series turns, the field will vary with the load, and will, if once adjusted to give good commutation at any one load, keep the same proportion for any other load, provided the iron parts of the circuit are not too highly saturated.

Interpoles are also known as *commutating poles*, *compensating poles*, *reversing poles*, or *auxiliary poles.*

Alternating-current motors of the commutator type are also often provided with commutating poles between the main field-magnet poles to produce a reversing field in which commutation can be effected without sparking. See COMMUTATION; REVERSING FIELD.

Interrupter, Atonic, an interrupter for induction coils which can be adjusted so as



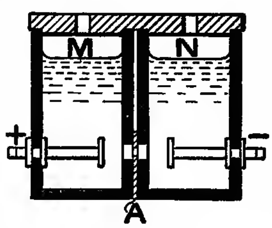
Atonic Interrupter

to operate at any desired frequency throughout a wide range. An interrupter of this type is described in paragraph 254 of the sixth section of McGraw's 'Standard Handbook for Electrical Engineers'. See AUTOMATIC INTERRUPTER; RECTIFIER.

Interrupter, Automatic. See AUTOMATIC INTERRUPTER.

Interrupter, Electrolytic. See RECTIFIER; INTERRUPTER, SIMON; INTERRUPTER, WEHNELT; AUTOMATIC INTERRUPTER.

Interrupter, Simon, an interrupter of the electrolytic type, in which the interruptions occur when the current density in the electrolyte at a hole in the porcelain plate A (in the fig.) interposed between the two compartments M and N, becomes sufficiently high. The position of the porcelain plate A has to be occasionally renewed, since the hole gradually becomes enlarged with use. See INTERRUPTER, WEHNELT; AUTOMATIC INTERRUPTER; RECTIFIER.



Simon Interrupter

Interrupter, Wehnelt.—The essential components of this piece of apparatus consist of an electrode (preferably of lead) of considerable area, opposed to a second electrode of very small area, usually a small length of platinum wire, both contained in a large vessel of dilute sulphuric acid. Such a combination when supplied with cc gives an interruption of very hf and great regularity, providing the circuit on which it is to work is sufficiently inductive. Caldwell and Campbell-Swinton have produced interrupters on the same principle, but in which both electrodes have considerable area, but are separated by an insulating partition in which there is a small aperture. It is important in all cases that the temperature of the electrolyte be kept well below 100° C. for the efficient working of the interrupter. See AUTOMATIC INTERRUPTER; RECTIFIER; INTERRUPTER, SIMON.

Intrinsic Brightness, the amount of light emitted per unit area of a source, measured in candles per sq cm. Solomon, on p. 31 of his treatise entitled 'Electric Lamps', defines this term as follows:—

'*Intrinsic brightness*, or simply *brightness*, is the cp emitted normally by unit area of the source. The quantity is not frequently used, but its importance is gradually obtaining recognition. The intrinsic brightness of a lamp is the property which, when high, is most harmful to the eyes. The brightness of an illuminated surface is the property which enables it to be seen. This depends on the illumination and on the nature of the surface.'

The 1896 Geneva Congress has recommended the pyr per sq cm as the unit of brightness. Solomon states that 1 pyr per sq cm is equal to 5·9 candles per sq. in.

Intrinsic Brilliancy, the amount of light per unit area of the source from which the light emanates.

Inverse Induced Current. See CURRENT INDUCTION.

Inverse Squares, Law of. See LAW OF INVERSE SQUARES.

Inversion, Thermo-electric. See THERMO-ELECTRICITY.

Inverted Arc Lamps. See LAMP, ARC.

Inverted Converter. See ROTARY CONVERTER.

Inverted-pyramid Type Aerial Transmitter. See TRANSMITTER.

Involute Connections. See CONNECTIONS, BUTTERFLY.

Involute Gear. See GEARING FOR ELECTRIC MOTORS.

Ion.—Kershaw in his treatise on 'Electrometallurgy' defines ion as follows: 'An electrically charged atom, or group of atoms, present in any electrolyte'. See also IONISATION; ELECTROLYSIS.

Ionisation.—In its normal state a gas is an almost perfect insulator, but under certain conditions it may become more or less a conductor. Research has shown that this conductivity is due to the presence of certain minute bodies which have the power of conveying electricity, and which move with great rapidity in an electric field. To these particles the name *ions* (see ION) has been given, and the gas which contains them is said to be *ionised.* The mass of the ions is in general so small that they appear to be parts of atoms.

The following are some of the known causes of ionisation:—

1. The action of light on metallic surfaces.
2. Dielectric stress.
3. Electric discharges, such as brush discharges.
4. The presence of flame or other intensely heated bodies.
5. Radioactivity, or the projection of ions from certain elements, such as radium, polonium, actinium, thorium, and uranium.

Discharges never pass through a gas unless it has first been ionised. See 'Insulation Breakdown' under INSULATION. (Ref. 'Conduction of Electricity through Gases', J. J. Thomson; 'Radioactivity', E. Rutherford.)

Ionise. See IONISATION.

Iridium Lamp. See LAMP, INCANDESCENT ELECTRIC.

I^2R Loss. See LOSS, COPPER.

Iron.—Iron is generally available in two distinct forms—*cast* and *wrought.*

CAST IRON is distinguished by its low melting-point (about 1200° C.), low tenacity, considerable stiffness, and very small deformation before fracture. Its ultimate tensile strength is about 7·5 tons per sq in (some 1100 to 1200 kg per sq cm). The peculiar properties of cast iron are due to the presence of 2·5 to 5 per cent of carbon. Grey cast iron has some 3 per cent of combined carbon and 2 per cent of free (graphite). White cast iron has no free carbon.

WROUGHT IRON is distinguished by high melting-point (about 1600° C.), high tenacity, ductility, and malleability, and great deformation before fracture. It can also be welded, while cast iron cannot. Good wrought iron should not contain more than 0·015 to 0·35 per cent of combined carbon, and no free carbon. Its ultimate tensile strength ranges from 18 to 28 tons per sq in (some 2800 to 4300 kg per sq cm).

In the electrical industry cast iron is used for yokes, spiders, bedplates, pedestals, and other mechanical parts. It is not greatly employed for carrying magnetic flux except in the yokes and poles of continuous machines. Wrought iron is little used in electrical machinery except for bolts and similar details, but steel, which is merely a special form of iron, is employed to an enormous extent. See STEEL; FERRO-ALLOYS.

Iron and Steel Testing. See TESTING SHEET IRON AND SHEET STEEL; DRYSDALE METHOD OF TESTING IRON AND STEEL; HOPKINSON METHOD OF IRON TESTING; WATTMETER METHOD OF TESTING IRON AND STEEL; 'Bridges for Magnetic Measurements' under BRIDGES; GRASSÔT FLUXMETER; STEP-BY-STEP METHOD OF MAGNETIC TESTING; RING METHOD OF MAGNETIC TESTING; PERMEAMETER; EWING CURVE-TRACER; EWING HYSTERESIS TESTER; BLONDEL HYSTERESIMETER; TESTER, EPSTEIN HYSTERESIS; RICHTER METHOD OF TESTING SHEET IRON; HUGHES INDUCTION BALANCE.

Ironclad Electromagnet. See ELECTROMAGNET, IRONCLAD.

Ironless Inductance. See INDUCTANCE, IRONLESS.

Iron Loss. See LOSS, IRON.

Iron Loss, Separation of. See WATTMETER METHOD OF TESTING IRON AND STEEL.

Iron Resistance. See RHEOSTATS OR RESISTANCES.

Iron Testing. See IRON AND STEEL TESTING.

Irregularity Factor, a term, applied chiefly to direct-connected ac generating sets, which denotes the maximum variation in velocity during a revolution. If the angular velocity is denoted by ω, then the irregularity factor is equal to—

$$\frac{\omega\ \text{max} - \omega\ \text{min}}{\omega\ \text{mean}}.$$

For a load comprising synchronous converters, the irregularity factor is preferably not allowed to exceed 1 in 200, *i.e.* one-half of one per cent. For less sensitive loads, a higher irregularity factor may be permitted. See also CYCLIC IRREGULARITY; CRANK-EFFORT DIAGRAM; TORQUE DIAGRAM OF AN ENGINE.

Irregular Rotating Field. See FIELD, ROTATING.

Irwin Oscillograph. See OSCILLOGRAPH.

Isolated Plant.—This term is generally used to designate generating plants put down by private users for their own supply, as distinguished from plants put down for the supply of electricity to the public. Thus a small plant for lighting a country mansion, or a plant put down by an engineering firm to supply current for driving their shops, would both be examples of isolated plants.

Isolit, the trade name of an impregnated papier mâché. It is extremely light, and, to a certain extent, tough, but it is inclined to be somewhat short. Its use is limited chiefly to the manufacture of small bobbins, bushings, and similar pieces.

Ivoride, the trade name of a hard-rubber substitute, closely resembling vulcanised fibre in some of its properties. It is hard and tough, and does not absorb water. It takes a high polish, and can be sawn, drilled, or threaded; though not non-inflammable it does not readily burn. See INSULATOR.

IWG, imperial wire gauge; the recognised British gauge for the specification of circular wires. See SWG.

J

Jack. See ANSWERING JACK.

Jack, Five-point, a telephone plug switch making five circuits in one motion of the hand.

Jack, Telephone. See TELEPHONE JACK.

Jack-box, the part of the equipment of a telephone exchange which contains the jacks.

Jack-sleeve, the tubular portion of a telephone jack.

Jacobi's Étalon. See RESISTANCE, JACOBI'S UNIT OF.

Jaconet Tape, the trade name of a cotton tape extensively used for insulating purposes. See TAPE FOR INSULATING PURPOSES.

Japanese Paper, a term applied to a very thin rag-paper. It is tough, and can be manufactured in thicknesses of from 0·025 mm. to 0·050 mm. This exceeding thinness renders it extremely useful for the manufacture of mica-paper, and the insulation of laminations, for which purposes it is extensively employed. See 'Insulation of Laminations' under INSULATION; MICARTA.

Japan Varnishes.—These are oil varnishes, and may be manufactured for either baking or air-drying. They dry with a black glossy surface which is very hard and durable. See INSULATING VARNISHES.

Jet Condenser. See CONDENSER, STEAM.

Jewels for Measuring Instruments. See SUSPENSION (IN MEASURING INSTRUMENTS).

Jig, a train of electrical waves of a frequency of the order employed in wireless telegraphy, *i.e.* from 50,000 to 10,000,000 per sec. If produced by a spark, it is damped.

Jigger, a transformer of few turns used in the receiver of a wireless telegraph station. The dimensions are such that it forms part of an oscillating circuit whose natural frequency is the same as that of the aerial and transmitter circuits.

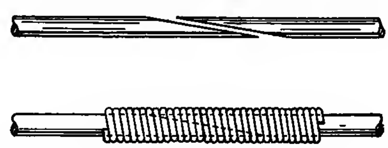
Jockey Pulley. See GEARING FOR ELECTRIC MOTORS.

Johnson-Lundell Regenerative Control System. See REGENERATIVE CONTROL SYSTEMS.

Johnson-Lundell Surface-contact System. See SURFACE-CONTACT SYSTEM.

Joint, Rail. See BOND; CONTINUOUS RAIL JOINT; WELDED RAIL JOINT; RENEWABLE RAIL JOINT.

Joint, Scarfed, a joint made between two conductors by filing down the ends to



Scarfed Joint

be joined until they are bevel-shaped and exactly fit one to the other, and then binding over the joint with a fine wire, say a No. 20, and soldering the whole together. If stranded cables are to be so joined, the strands at the ends of each cable are twisted tightly together with the pliers, and the ends soldered solid, before the filing to a bevel is begun.

Joint, Sleeve, a joint between two cables made by means of a metal sleeve soldered over the cables (see fig.).

Sleeve Joint

Joint, Spliced, a joint between two cables made by intertwining the separate strands of the cables and binding them each round the opposite cable. Fig. 1 shows the method of preparing the cables for such a joint. The insulation is cut away from each cable for a distance of about 15 cm from the

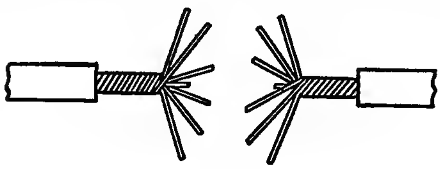


Fig. 1

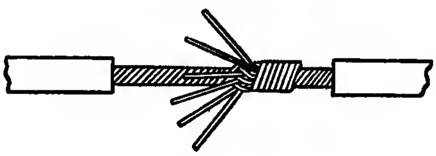


Fig. 2

Spliced Joint

end (assuming, say, 7/16 cable), and the individual wires are splayed out for about 7·5 cm of this distance. The centre wires are then cut short, as shown in the illustration, and the two cables butted together with the splayed ends intertwining. These ends are then twisted round the opposite cables, as shown in fig. 2. Finally, the joint is soldered, and reinsulated. (Ref. 'Internal Wiring of Buildings', H. M. Leaf.)

Joint, Staggered. See STAGGERED JOINT.

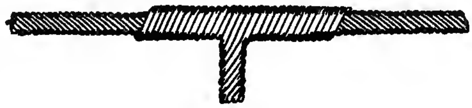
Joint, Straight-through, a joint between two conductors where the circuit is

Straight-through Joint

not required to be branched. The illustrations of JOINT, SPLICED, relate to a straight-through joint.

Straight-through joints may also be made by the aid of so-called *jointing pieces* or *thimbles*, which may be of a great variety of designs, but which all have for their object the provision of an expeditious and effective method of making joints. One type of jointing-piece for a straight-through joint, is illustrated in the accompanying fig.

Joint, T, a type of joint frequently employed where it is required to lead off a



T-Joint

branch from a conductor. One form of **T**-joint is shown in the fig.

Joint Box. See BOX, JOINT.

Joint-box Compound. See INSULATING COMPOUND; BITUMEN.

Joint in High-pressure Cables. See HIGH-PRESSURE CABLE JOINT.

Jointing Aluminium Conductors.—For some time the extensive use of aluminium in the electrical industry was retarded by the difficulties encountered in making joints. These difficulties now appear to have been satisfactorily overcome in various ways, amongst which may be mentioned the following.

'RUN' WELDED JOINT, a method of making a joint, which is suitable for aluminium stranded cables and conductors of large diameter. The two ends of the wire or cable to be joined are cut off square, and are carefully cleaned of all grease or other foreign substances, so as to ensure good electrical contact in the finished joint. In the case of insulated cables the insulation should be bared for a few inches back at the end of each cable, and the wires should be carefully cleaned. The two ends of the cable are then brought together, and a tubular cigar-shaped metal mould is clamped around the joint. Aluminium, which has been previously melted in a crucible over an ordinary portable fire, is then poured into the mould through a hole provided in the centre of the mould for that purpose. The mould and cable-ends should be previously heated to avoid chilling of the first portion of the molten aluminium entering the mould. After the metal has been allowed to set, the mould is removed, and the joint should be trimmed with a rough file and with emery paper. To ensure a good joint, free from blowholes, only the purest aluminium should be used. It should be poured as soon as it has reached its melting-point, care being taken not to overheat it, and not to expose it for any length of time to the action of the hot gases of the stove, since molten aluminium has the property of absorbing gases, which are occluded when the metal cools down. For making **T**-joints and for joining up feeders or service mains, a modification of this method is employed, the mould being designed to accommodate the third wire at right angles to the main cable.

M'INTYRE JOINT.—In jointing aluminium conductors the M'Intyre mechanical joint

Fig. 1.—M'Intyre Joint

shown in fig. 1 has been extensively employed. It is made by threading the two ends of the wire to be joined through opposite ends of an oval-shaped, soft aluminium tube. This is then given a few twists with the pliers, after which the loose ends of the wire are bent once round the conductor, and are then cut off.

MECHANICALLY-WELDED JOINT.—A simple method of joining small-diameter wires—

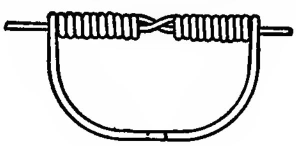


Fig. 2

Fig. 3

Twist Joints

which is extensively used with aluminium wires owing to the difficulties attending the soldering of aluminium—consists in twisting the two wires together and bending the free ends over in the form of a semicircle, and finally welding these ends in the flame of a blow lamp. The ends may either be allowed to hang down in the form of a loop, as in fig. 2, or they may be bent round the joint, as shown in fig. 3.

BUTT-WELDED JOINTING OF ALUMINIUM CONDUCTORS.—Solid aluminium conductors, up to some 18 mm diameter, may be joined by simple butt-welding in the flame of a blow lamp, or the joint may be enclosed in a special sleeve heated from the outside. End pressure is applied to the wires at the moment of welding, in order to drive out the film of oxide. A butt-welded joint is shown in fig. 4.

Fig. 4.—Butt-welded Joint

See also WELDING, AUTOGENOUS; ALUMINIUM.

Joubert Contact Method.—For obtaining the emf wave of an alternator, Joubert fixed a rotating contact to the shaft, and by its means applied the instantaneous emf to a condenser and electrostatic voltmeter in parallel. The voltmeter then read the instantaneous emf, and the position of the stationary contact could be varied to obtain any point on the wave. See OSCILLOGRAPH.

Joule.—The joule is the physicist's unit of energy. It is equal to 10^7 cgs units, *i.e.* 10^7 ergs. 1 joule per sec = 1 w. The commercial unit of energy, the kelvin (the preferable name for the kw hr), is equal to 3,600,000 joules.

1 joule = 0·000000278 kelvin.
= 0·000239 kg cal.
= 0·102 kg m.

Joule Effect. See HEATING EFFECT OF CURRENTS.

Joule's Equivalent.—Joule found that when heat is produced by mechanical work, there is a fixed relation between the work done and the heat produced. The number of ft lb required to produce one heat unit is known as *Joule's equivalent* or the *mechanical equivalent of heat.* 778 ft lb of work are required to raise 1 lb of water through 1° F. 427 kg m are required to raise 1 kg of water through 1° C. 367,000 kg m are equal to 1 kelvin (kw hr).

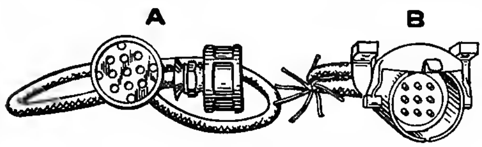
Joule's Law, the law of the heating of a conductor carrying a current. This law states that the heat produced by a current I flowing through a resistance R for time t is equal to

$$I^2 R t.$$

With I in amp, R in ohms, and t in sec the heat evolved will be in w sec (joules), and must be multiplied by 0·24 to convert to calories (gram-degree calories).

Jumper.—On dynamos and in other places where a connection is made to an equalising bar or lead, the short piece of conductor used for the purpose is sometimes termed a *jumper.*

Jumper, or **Bus-line Jumper Receptacle,** the name given to part of the coupling arrangement used in the multiple unit control system to connect corresponding cables



A, Jumper. B, Coupler Socket.

between the ends of two coaches. The complete 'control cable coupler', connecting the control cables on adjacent motor cars or motor car and trailer, consists of a 'coupler socket' attached to the car, with insulated metal contacts connected to the train wires, and of a removable 'coupler plug' containing corresponding insulated contacts.

The two plugs necessary for interconnection have corresponding contacts connected by a short flexible cable—this combination is the 'jumper' proper—the plugs being fitted into the sockets on the cars and automatically spring-secured.

Junction Box. Synonymous with Cable Box. See Box, Cable; Box, Joint.

Jungner Accumulator, an iron-nickel accumulator. Jungner and Edison have independently developed iron-nickel accumulators. See Edison's Nickel-steel Accumulator.

Jute-insulated Cables. See Cable, Underground.

K

Kalkos Conduit System. See Tubing, Tinned.

Kapp Coefficient.—If, in the armature of an alternator, E is equal to the virtual (*i.e.* the effective or root-mean-square) value of the emf, ~ is equal to the frequency in cycles per sec, T is equal to the number of turns in series, and M is equal to the flux per pole, in lines, then, in the case of an alternator,

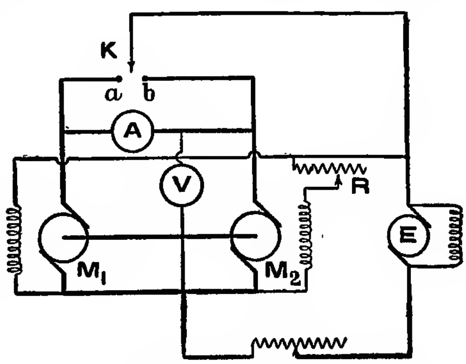
$$E = k \times \sim \times T \times M \div 10^8,$$

where k is a coefficient taking into account (1) the integration and reduction to a virtual value of the flux wave, and (2) the spreading factor, and (3) pitch factor of the armature winding. The basis of the coefficient was discussed at an early date by Prof. Kapp, and hence the name. The first component of the coefficient is 4·44 for a sinusoidal flux distribution, and the other two components will be found discussed under the two separate headings. See Spread Factor; Pitch Factor.

Kapp Line of Force. See Line, Kapp.

Kapp's Method of Testing Dynamos and Motors.—This is a modification of the well-known Hopkinson test, in which the losses in the combined machines are supplied electrically from the auxiliary generator E (see fig.).

In order that there shall be a circulation of power in the armature circuits, the field of M_2 is weakened by the rheostat R. With the switch K in position a, the ammeter A measures C_1, the current to the motor M_2, which is partly supplied from E and partly from M_1. With switch in position



Kapp's Method of Testing Dynamos and Motors

b, A measures C_2, supplied only from M_1. Then $\frac{C_2}{C_1}$ is the overall efficiency of the combination, and for similar machines.

$$\eta \text{ of one machine} = \sqrt{\frac{C_2}{C_1}}.$$

The pressure is indicated by the voltmeter V.

(Ref. Gisbert Kapp, Elec. Engr., Jan. 22 and 29, 1892.)

Kathions. See Electrolysis.

Kathode. See Cathode; Electrolysis.

Kathodic indicates relation to the kathode (cathode), *i.e.* to the electrode by which positive electricity flows away.

Keeper. See Magnet Keeper.

Keller Electric Furnace. See Furnace, Electric.

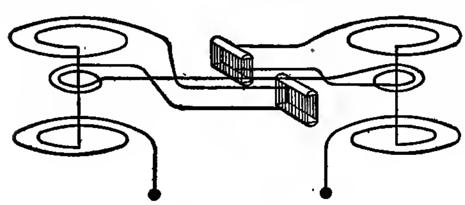
Kelvin, a term gradually coming into use to denote the quantity of energy heretofore generally known as *1 kw hr.* It is quite likely that the term will come to be widely employed to denote this quantity of energy even when not in the form of electricity.

Thus 1 kelvin is equal to ...
- 860 kg cal.
- 367,000 kg m.
- 1·34 hp hr.
- 3,411 B Th U.
- 2,659,000 ft lb.
- 3,600,000 joules.
- $3{,}600{,}000 \times 10^7$ ergs.

A *megakelvin* is a million kelvins, and a *millikelvin* is one-thousandth of a kelvin, *i.e.* a w hr.

It is useful to remember that 1·16 kelvin of energy is absorbed in increasing the temperature of 1 ton of water by 1° C.

Kelvin Balance.—This instrument consists of two sets of fixed and movable coils,



Kelvin Balance

so placed relatively, that on passing a current through them, the effect may be weighed. The kelvin balance may be used to measure current, potential, or power, but is essentially a current instrument. The movable coils are fixed in a horizontal plane to the two ends of the balance beam, and immediately below them are the fixed coils. The currents are then passed in such a direction as to deflect the beam, and it is restored to the symmetrical position by a sliding weight. A fine adjustment of the weight is obtained by a slider which is drawn along a scale at the front of the instrument. See also Ampere Balance.

Kelvin's Law. See Law, Kelvin's.

Kempe Discharge Key. See Key, Charge and Discharge.

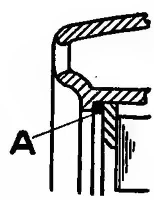
Kerosene Oil. See Paraffin Oil.

Kerr Effect.—Dr. Kerr, of Glasgow, discovered that the plane of polarisation of a polarised ray of light is affected by reflection from the end-face of a magnet, and that the angle through which the plane of the wave is turned depends on the intensity of the magnetisation. The discovery was important in connection with Clerk-Maxwell's electromagnetic theory of light.

Key, Charge and Discharge, a two-way key with exceptionally good insulation, generally mounted on three pillars of ebonite, one supporting the brass arm at the hinge, one a contact above, and one a contact below the arm. A spring is usually provided to keep the arm normally against the upper contact, and a catch to hold it in the intermediate or insulated position if desired.

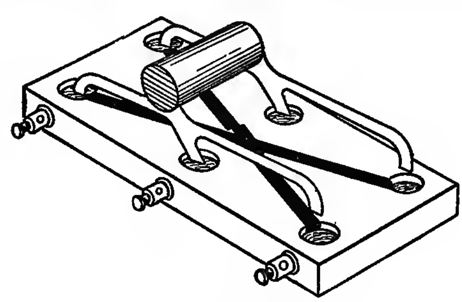
Kempe Discharge Key, a special form of discharge and charge key, in which two triggers are arranged, so that if the key is in the charge position, one trigger causes the arm to go to the 'insulated', and the other to the 'discharge' position on pressing.

Key, Circumferential. — Instead of drawing together by bolts the end flanges of the stators of dynamo-electric machines, a circumferential key may be employed. This consists of a steel ring as indicated in section at A in the fig. This ring is usually inserted while the flanges are retained under hydraulic pressure.



Circumferential Key

Key, Pohl's Commutator.—Six mercury wells are arranged to transfer any piece

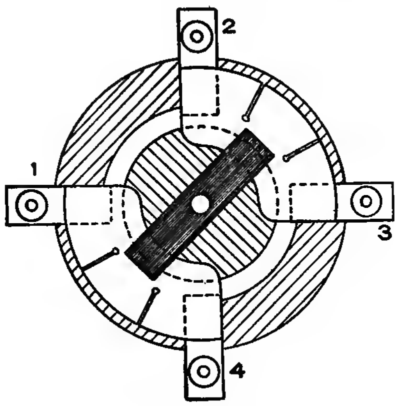


Pohl's Commutator Key

of apparatus from one circuit to another by means of a rocking switch. By cross-connecting opposite corners the arrangement becomes a reversing switch. It has the advantage of giving a low and constant contact resistance.

Key, Reversing, a key having four contacts equally distributed around a circle. Contact may either be made from 1 to 2 and

3 to 4, or from 1 to 4 and 2 to 3. Thus terminals 1 and 3 will be reversed with respect to 2 and 4 for alternative positions of the



Reversing Key

key. See also KEY, POHL'S COMMUTATOR; COMMUTATOR.

Key, Ringing. See RINGING KEY.

Key, Sliding-contact, a key used for making contact at any point along a wire, as in the potentiometer or slide-wire bridge. It consists of a wedge-shaped piece of brass mounted on a flat spring so that its lower edge would normally rest in contact with the wire. A press-button held up by a much stronger spring, however, prevents contact until it is depressed, so that the pressure of contact depends entirely on the strength of the spring carrying the contact piece.

Kg, the preferable abbreviation for *kilogram.*

Kg cal, the preferable abbreviation for *kilogram calorie.*

Kg m, the preferable abbreviation for *kilogram-meter.*

Kicking Coil. See COIL, KICKING.

Kilo-ampere Balance. See AMPERE BALANCE.

Kilogram, the weight of 1 cu dm of water; *i.e.* of 1 liter of water.

1 kg = one-thousandth of one ton.
1 „ = 1000 g.

Kilogram Calorie, the quantity of energy required to raise the temperature of 1 kg of water from 0° C. to 1° C.

1 kg cal = 0·00116 kelvin.
= 427 kg m.
= 4190 joules.

Kilogram-meter, the quantity of energy required to raise 1 kg through a height of 1 m.

1 kg m = 0·00272 millikelvin.
= 0·00234 kg cal.
= 9·81 w sec.
= 9·81 joules.

Kiloline, a unit of magnetic flux, being one thousand cgs magnetic units; largely used in specifying flux densities in dynamo-electric machines. See LINE OF INDUCTION; MAXWELL.

Kilovolt-ampere, a unit of 'apparent' power which for unity pf is equal to one kw. See also VOLT-AMPERE.

Kilowatt (preferable abbreviation = *kw*) denotes an amount of power equal to 1000 w. The kw is generally used as the unit in rating generators, transformers, &c., as it is a more convenient size than the w. A kw is a rate of expenditure of energy of 1 kelvin per hr.

Kilowatt-hour (preferable abbreviation = *kw hr*) denotes an amount of energy equal to that delivered in one hour by a source of electricity which gives out power at the rate of 1 kw. Preferably designated *kelvin* (which see). See also BOARD OF TRADE UNIT.

Kilowatt-hour Meter. See METER, ENERGY.

Kinetic Energy. See ENERGY, KINETIC.

Kinetic Energy of Armature. See ENERGY, KINETIC, OF ARMATURE.

Kingsland Surface-contact System. See SURFACE-CONTACT SYSTEM.

Kirchhoff's Laws. — *Kirchhoff's Law of Electric Circuits* amounts practically to a statement that electric current cannot be dissipated in a conductor, *i.e.* that as much comes out at one end as has gone in at the other. This is true for continuous-current circuits, and for circuits in which the capacity is negligible. In its simplest form the law states that if any number of conductors are connected at a point, the sum of the currents flowing into the point is equal to the sum of those flowing out from it.

Kirchhoff's Law of Radiation asserts that, 'At any given temperature, a body emits just that variety of radiation which it is also capable of absorbing at that temperature'. This law is only applicable to temperature radiation.

Kjellin Electric Induction Furnace. See FURNACE, ELECTRIC.

Km, the preferable abbreviation for *kilometer.*

Km phps, the preferable abbreviation for *kilometers per hour per second.*

Knee of Saturation Curve, the point of magnetisation beyond which the permeability of iron diminishes rapidly. See point K of illustration accompanying definition of MAGNETISATION, CURVE OF.

Knife Suspension. See SUSPENSION (IN MEASURING INSTRUMENTS).

Knife Switch. See SWITCH, KNIFE.

Kohlrausch Bridge Methods.—The ordinary methods available for testing wire resistances cannot be used for determining the resistance of electrolytes on account of the counter emf due to polarisation set up when current passes through them. To eliminate this effect, the bridge of the ordinary Wheatstone form is supplied with current from an alternating source, such as an induction coil or transformer. The ordinary galvanometer is, however, incapable of responding to such a current, and must be replaced by a telephone receiver. Measurements are then conducted in the same way as for ordinary wire resistances, balance being obtained when the sound in the telephone is weakest or entirely absent.

A modification of the above method has been employed by Kohlrausch, in which the telephone is replaced by the swinging coil of his unifilar dynamometer (the fixed coils of which are included in the main circuit of the bridge), and is therefore traversed by a constant current. Under these conditions it behaves exactly as an ordinary galvanometer.

Korn's Phototelegraph. See PHOTOTELEGRAPHY.

Kreisler's Induction Coil. See COIL, INDUCTION.

Kruppin, a high-resistance material manufactured by Messrs. Krupp of Essen. It is said to be an alloy of nickel and iron. Its specific resistance is 85 microhms per cm cube at 0° C., and its temperature coefficient is 0·00077, *i.e.* its resistance increases only 0·077 of 1 per cent per 1° C. increase in temperature. Its tensile strength is stated to be 6000 kg per sq cm. See HIGH-RESISTANCE ALLOYS; WIRE, RESISTANCE.

Küch Lamp. See LAMP, TUBULAR.

Kva, the preferable abbreviation for *kilovolt-ampere* (which see).

Kw, the preferable abbreviation for *kilowatt* (which see).

Kw hr, the preferable abbreviation for *kilowatt-hour* (which see).

L

La Cour Motor Converter. See CONVERTER, CASCADE.

Lacquer for Lamination Insulation.—Lacquers are spirit varnishes of thin consistency, giving a thin, tough coat. Their use for the insulation of laminations is not general practice on account of their cost, but apart from their high cost, lacquers are very suitable for the purpose. See CORE-PLATE VARNISHES; DISCUM VARNISH; INSULINE; 'Insulation of Laminations' under INSULATION.

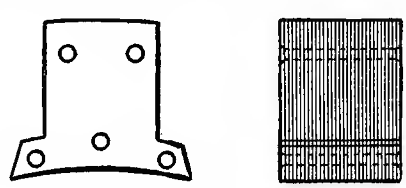
Lag denotes the condition where the phase of one ac quantity lags behind that of another. The term is generally used in connection with the effect of inductance in causing the current to lag behind the impressed emf. See PHASE; PHASE DISPLACEMENT; POWER FACTOR; ANGLE OF LAG.

Lag, Angle of. See ANGLE OF LAG; LAG; PHASE DISPLACEMENT; POWER FACTOR.

Lambert's Law. See LAW, COSINE.

Lamellæ, thin plates, more especially the iron plates of which laminated parts of magnetic circuits are built up. See CORE DISKS; CORE, ARMATURE; LAMINATED; ENERGY LOSSES; LOSS, HYSTERESIS.

Laminated, built up of comparatively thin sheets laid side by side instead of being made of solid metal. Parts of electric machinery subject to a variable magnetic flux, both iron parts of the magnetic circuit and copper bars carrying current, require in many instances to be laminated in order to diminish the losses due to eddy currents.



Laminated Core for a Field-magnet

LAMINATED CORE, an armature or field-magnet core built up of thin iron sheets. A laminated core for a field-magnet is shown in the fig.

LAMINATED MAGNET, a magnet built up entirely of thin iron sheets laid side by side.

LAMINATED POLE SHOES, pole shoes built up of thin iron sheets laid side by side. Usually applied to the construction in which laminated pole shoes are attached to a solid magnet, in contradistinction to the term *laminated magnet*, when the whole magnet core is laminated. See also 'Laminated Brush' under BRUSH; YOKE, LAMINATED; CORE DISKS; CORE, ARMATURE; LAMINATION OF MAGNET; ENERGY LOSSES; LOSS, HYSTERESIS.

Lamination of Armature Conductors.—Armature conductors are laminated for two reasons; firstly, to increase their flexibility, and secondly, to eliminate eddy-current losses. This latter object will not be completely fulfilled unless the elements of the conductor be transposed or twisted together. In deep, solid conductors, eddy currents may, in extreme cases, increase the copper loss to several times the value it would have if only the load current were involved. Some form of lamination becomes a practical necessity in such cases. See STRANDED CONDUCTOR. (Ref. A. B. Field, Proc.A.I.E.E., xxiv, p. 761; M. B. Field, Elec., lvi, pp. 845, 884.)

Lamination of Magnet.—Magnets for use with ac must be built of laminated cores to avoid eddy currents. The laminations must be finer the higher the frequency and the higher the induction density. Magnets for use under any conditions in which they may have to change their magnetisation rapidly, or act instantaneously, must also be laminated to avoid the delay in magnetisation which would arise through the demagnetising action of eddy currents. See also TIME LAG OF MAGNETISATION; MAGNET, COMPOUND; LAMINATED; ENERGY LOSSES.

Permanent magnets are sometimes built up of highly magnetised thin strips of steel to obtain the highest possible intensity of permanent magnetisation. Such magnets are often called *compound magnets.*

Laminations, Armature, the sheet-iron or sheet-steel stampings which are built up to form the armature core. See CORE DISKS; LAMINATED.

Lamp, Arc.—The formation of an arc (which see) between two conducting electrodes may result in the production of light, either from the electrodes themselves or from the incandescent vapour of the arc thus formed. In the arc lamp the production of light in this way is utilised for the purpose of illumination. The electrodes are usually, but not invariably, composed of carbon, and the arc is usually enclosed by a suitable surrounding globe, which serves the double purpose of protecting the arc itself from draughts and diffusing the light from it. Arc lamps may be classified from several standpoints. In the first place they may be of either the open or the enclosed type.

OPEN-ARC LAMPS.—When air is allowed free access to the arc and to the electrodes between which it is formed, the arc is termed an *open arc*, and the lamp in which such an open arc is utilised is known as an *open-arc lamp.* The characteristics of an open-arc lamp are good efficiency and comparatively rapid wasting away of the carbons.

ENCLOSED-ARC LAMPS.—When the air is partially or wholly excluded from contact with the arc and with the electrodes between which it is formed, the arc is termed an *enclosed arc*, and the lamp in which such an arc is utilised is termed an *enclosed-arc lamp.* The characteristics of an enclosed-arc lamp as opposed to those of an open-arc lamp are, an increase in the time taken by the carbon to waste away, and a corresponding reduction in efficiency. In the enclosed-arc lamp the arc is much longer than in the open-arc lamp. Arc lamps may also be classified in accordance with the regulating mechanism employed in their design.

REGULATING MECHANISM OF ARC LAMP.—The chief functions of the regulating mechanism of an arc lamp are as follows:—

1. To separate the carbons when a pd is applied to the lamp, and so strike the arc.

2. To maintain at a determined correct value the length of the arc when struck.

3. To feed the carbons together in such a way as to compensate for the wasting away of the carbons.

The regulating system itself usually balances the force of gravity as represented by the carbons and their accessories, or the pull of a spring, or both, and the regulation is usually effected by means of electrcmagnets, actuated by the current passing through the lamp, or by the pd across the arc. The electromagnetic mechanism may be *series, shunt,* or *differential.*

Series-wound Arc Lamp.—In this case the current passing through the arc also passes through a solenoid composed of a few turns of thick wire in series with it. On applying a pd to the arc, the rush of current through the carbons (in contact) excites the solenoid, which in turn lifts the carbon and strikes the arc. In the same way, when the arc lengthens, the diminution in current thereby caused weakens the electromagnet, which therefore allows the carbons to fall together. Conversely, when the arc tends to shorten, the increase in current pulls the carbons apart.

Shunt-wound Arc Lamp.—The actuating solenoid consists, in this case, of a great number of turns of fine wire, and is placed in parallel with the arc. When there is no pd across the terminals of the arc, the carbons are separated. On applying a pd the electromagnet is excited, and brings the carbons together, striking the arc. In this case an alteration in the length of the arc alters the pd across it, and so causes the shunt mechanism to modify the position of the carbons.

Differentially-wound Arc Lamp.—In this case both a shunt and a series coil are used conjointly, in an attempt to combine the features of both systems.

Hot-wire Arc Lamp Regulating Mechanism.—Instead of the usual electromagnetic action, the expansion of a wire heated by the passage of a varying current has been utilised to regulate the position of the carbons.

Hand-regulated Arc Lamp.—The length of the arc can be maintained at its correct value by an attendant, who continually feeds the carbons together by hand as they waste away. The mechanism of such a lamp is termed a *hand-regulated mechanism.*

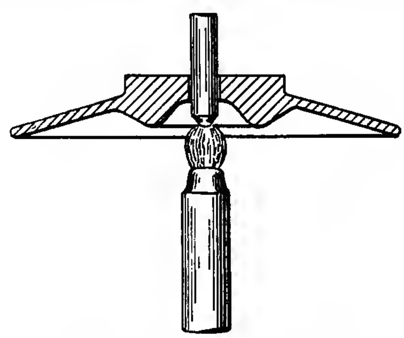
Trimming of Arc Lamps.—In order that the arc lamp may continue to burn successfully, occasional attendance is necessary, for the purpose of placing new carbons in the lamp, seeing that the carbons are central, that the regular lighting-mechanism of the lamp is working smoothly, &c. The attention to these details is summed up by the term *trimming.*

Double-carbon Arc Lamp (synonymous with Twin-carbon Arc Lamp).—In order to increase the period of burning of arc lamps, such lamps have been provided with two pairs of carbons, so arranged that, as soon as one pair has burned away, the second pair is automatically substituted. Such lamps are termed *twin* or *double-carbon* arc lamps.

Magazine Arc Lamp, a development of the *twin* or *double-carbon arc lamp.* Magazine arc lamps are provided with a series of carbons, which are automatically substituted for the consumed ones, so as to prolong the period of time before the lamp requires attention. The method has been recently applied especially to flame arcs, since these burn away rather rapidly.

Inverted-arc Lamps.—In the cc arc the greater part of the light comes from the incandescent crater of the positive carbon. It is, therefore, usual to make the upper carbon the positive one, in order that most of the light may be thrown downwards. In the case of the inverted arc the positive carbon is the lower one, with the result that the greater part of the light is thrown upwards, and is received on a suitable white diffusing surface which reflects the light irregularly downwards again; for this purpose the white ceiling of a room is sometimes utilised. The characteristic of this method of lighting is a thorough diffusion of the light and consequently a marked absence of shadows.

Flame-arc Lamp.—When the vapour of the arc formed between two conducting electrodes, and not the electrodes themselves, is the main source of light, the arc is termed a *flame arc.* A lamp utilising an arc of this description is termed a *flame-arc lamp* or *flame lamp.* In order to produce an arc of this nature, special carbons are employed which are termed *flame carbons* (which see). An arc lamp of this description is also known as a 'luminous' arc lamp. Amongst the types of flame-arc lamp may be mentioned the *Bremer* and the *Excello* (see below) lamps. In the flame-arc lamp the length of the arc



Carbon and Economiser of a Flame-arc Lamp is very considerable. The two carbons of a typical flame-arc lamp, together with the economiser (see ECONOMISER FOR ARC LAMP), for reflecting the light downward, are shown in the fig.

CARBONE ARC LAMP, a form of arc lamp utilising inclined carbons, and a feature of which, it is claimed, is the production of 'white' light.

EXCELLO ARC LAMP, an efficient form of flame-arc lamp (see above) utilising inclined carbons, and producing a yellowish-coloured light.

MAGNETITE ARC LAMP, a form of arc lamp in which the negative terminal consists of a special material, said to be chiefly composed of magnetite to which traces of titanium and other oxides are added. The positive electrode may be formed of any good conducting material, but copper is frequently employed. A long arc is formed, which is itself the chief source of light, and the precise spectral character of which is decided by the material of the negative electrode. This is usually so chosen as to yield as white a light as possible.

The chief characteristic of the magnetite arc is the slow rate at which the negative burns away (the positive remaining practically unconsumed). It is said that the negative electrodes can be so prepared as to last as long as 400 to 600 hr, while the power consumption of the arc under the best conditions approaches the low value of 0·25 wpcp.

VOGEL ARC LAMP, an enclosed-arc lamp, in which mercury and potassium—or sodium—amalgam vapour is allowed free access to an arc originally struck between carbon electrodes. In this way it appears that the globe as a whole becomes filled with luminescent mercury, giving a powerful and efficient light. (See 'Electrotechnik und Maschinenbau', vol. xxiv, p. 423, 1906.) In tests made on this type, the length of the arc and the intensity of the light varied greatly. The burning hours per trimming were considerably increased. See 'Mercury Vapour Lamp' under LAMP, TUBULAR.

MINIATURE ARC, a diminutive type of enclosed arc of small current consumption. Other similar types of small arc lamps are known as the *Lilliput*, *Midget*, &c.

DASH-POT OF ARC LAMP consists of a piston working in a closed cylinder, and connected with the lever mechanism controlling the position of the electrodes. In its downward motion the piston compresses the air in the cylinder, and the inertia of the piston serves to prevent violent fluctuating movements on the part of the regulating mechanism of the lamp.

CLUTCH OF AN ARC LAMP, the arrangement used to grip the electrodes of an arc lamp. See ARC; CARBONS, ARC LAMP; ARC LIGHT. (Ref. 'Electric Arc Lamps', Zeidler and Lustgarten; 'The Electric Arc', Mrs. Ayrton.) [L. G.]

Lamp, Cell-inspection, for Accumulators, a small thin incandescent lamp attached to a long piece of ebonite which can be passed between the plates of a cell when it is desired to ascertain their condition, or the depth of the deposit underneath them. A 1 pr is usually employed, and the necessary current can be obtained by attaching clips to the terminals of a single cell—if desired, to those of the cell it is proposed to examine.

Lamp, Efficiency of.—

GENERAL SENSE: the ratio (for any lamp) of the amount of energy transformed into light to the total energy supplied.

RESTRICTED SENSE: the cp which a lamp yields per w supplied to it. The wpcp of a lamp is an expression which is often used in technical literature as if it were synonymous with efficiency. It would be more correct to call it the *inefficiency of the lamp*. See INEFFICIENCY OF ELECTRIC LAMPS.

Lamp, Fleming-Ediswan Large-bulb Standard, a secondary electric standard designed by Fleming, and manufactured by the Ediswan Company. The lamps are made for pressures up to 100, and for cp ranging from 10 to 16. The filaments are of horseshoe pattern, and the bulbs are large. This is in order to ensure a large vacuous space, and also to distribute over as large an area as possible the particles of carbon which may be thrown off from the filament. The filaments are aged by the makers for a time before being sealed into the large bulbs. (Ref. Elec. Engr., Aug. 26, 1904; Journ.I.E.E., vol. xxxviii, p. 287.)

Lamp, Incandescent Electric, or Glow.—By this term is understood a lamp consisting essentially of a solid conductor, the temperature of which is raised to a high value, at which the solid becomes incandescent.

[For the purpose of the Phœnix Fire Office Rules (which see) an incandescent lamp is defined as 'An exhausted and hermetically-sealed glass bulb containing a filament of carbon (or other suitable substance) connected with the exterior of the bulb by connecting wires, for conveying electricity to the filament to render it incandescent'.]

The first incandescent lamps came into commercial use about 1880, and were due to the almost simultaneous efforts of Swan in Britain and Edison in America. The latter, in his original patents, referred to lamps in which the filament consisted of a length of fine platinum wire.

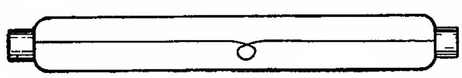
Carbon-filament Lamps

Subsequently carbon filaments, manufactured in various ways, were used. Edison at first utilised carbonised bamboo, but a little later carbon filaments were made by the modern method of squirting, and afterwards carbonising, by suitable processes, a solution of cotton wool dissolved in zinc chloride. In the case of all carbon filaments it is essential to enclose the filament in an exhausted glass envelope in order to avoid destruction of the filament by oxidation.

Efforts have been made to secure filaments which would, without deterioration, stand a higher temperature of incandescence than the original carbon ones. The so-called 'metallised' or 'graphitised' filament (see Filament) is an example of the most recent outcome of these efforts.

Gem Lamp, a form of incandescent electric lamp in which a graphitised carbon filament (see Filament) is utilised. G E M is a word coined from General Electric (America) Metallised.

Linolite Lamp, a variety of incandescent filament lamp in which the ordinary bulb is



Linolite Lamp

replaced by an elongated tube, and in which an ordinary filament is stretched out so as to provide a lineal form, as shown in the diagram, the current entering at the two extremities of the filament. The lamp is equipped with a reflector, usually composed of aluminium. The trade name has recently been changed to *Tubolite Lamp*.

Lamps with Filaments of Refractory Rare Earths

More recently many types of incandescent lamps using filaments composed of materials other than carbon have been devised. Nernst has utilised filaments composed of refractory rare earths. These are sufficiently refractory and non-oxidisable not to require an exhausted envelope. Lamps having filaments composed of rare and refractory metals have also been invented, and in some cases carbides and other metallic compounds have been used.

Nernst Lamp.—In this lamp, a filament composed of rare earths, such as magnesia, zirconia, yttria, &c., is used. Such filaments do not conduct in the cold state, and therefore their employment has hitherto required the addition of a heating coil surrounding the filament and in parallel with it, this heater being cut out of circuit automatically when once the process of conduction commences. The great sensitiveness of the filament to variations in pressure also necessitates the insertion of a special compensating iron-wire resistance in series with it.

The refractory nature of the glower permits of a higher temperature than is possible in the case of carbon lamps, and an energy consumption of about 1·5 wpcp results. A vacuum is unnecessary and indeed undesirable in the case of Nernst filaments.

Metallic-filament Lamps

A few years ago efforts began to be made to manufacture glow-lamp filaments capable of withstanding a higher efficiency of incandescence than those made of carbon, by the use of refractory metals. A material intended for this purpose must be capable of withstanding a high temperature of incandescence, and must also have a sufficiently high resistance. At present such lamps can be made capable of yielding a life of over 1000 hr at a consumption of 1 wpcp. The resistance of the material used is, however, undesirably low. Hence such lamps cannot at present be produced for sufficiently h pr in sufficiently small units. Thus, in this country, 200-volt metallic-filament lamps of less than 25 cp are not yet produced on a commercial scale, while 100-volt lamps as low as 12 cp are only beginning to be generally available. Mordey has made the excellent suggestion that the term *wire lamp* be substituted for the term *metallic-filament lamp*.

The following are some examples of lamps with metallic filaments.

Tungsten Lamps.—The main constituent of the filaments of lamps included in this class is usually tungsten, though the processes, which are still developing, admit of the addition of other rare metals.

Tungsten filaments are made by three chief processes.

1. The *substitution process*, by which an originally carbon filament is gradually converted into tungsten by deposition of the latter metal from a suitable gaseous compound. See, for instance, the method of Just and Hahnemann (Brit. patent, No. 11,949 of 1905).

2. The *paste process*, in which the metal is reduced to a very fine paste, mixed with some binding material, and squirted into a filament, which is subsequently sintered together into a homogeneous and conducting state by the passage of an electric current. Lamps are manufactured by this process, and sent out under the trade names of Osram, Osmi, and Osmium lamps.

3. *The colloidal process.*—By this process, the metal is reduced to a 'colloidal' or finely-divided gelatinous condition, such fine particles readily adhering together. It is then squirted into a filament, and subjected to subsequent treatment which renders the metal crystalline and conducting.

The *Kuzel lamps* are manufactured by this process, the metal being reduced to the colloidal condition by the formation of an electric arc between metallic electrodes under water.

Among other lamps belonging to the tungsten class may be mentioned those sold under the names of 'Z' lamps, Aegma lamps (which see), and Mazda lamps (which see). For most makes of tungsten lamps, an efficiency in the neighbourhood of from 0·8 to 1 cp (Hefner) per w and a useful life exceeding 1000 hr are claimed.

ZIRCON-WOLFRAM LAMP, a form of incandescent lamp in which a metallic filament stated to be composed of a mixture or alloy of wolfram and zirconium is utilized.

HELION LAMP.—This incandescent electric lamp is the invention of Parker and Clark. (Paper read before Am.Phys.Soc., New York, Dec. 29, 1906.) The filament is composed chiefly of silicon deposited over a carbon core by a special process. Such experiments as have been yet carried out on the lamps are said to show that filaments can be manufactured by this process with a life of over 1000 hr at an efficiency of 1 cp per w. It is also claimed that the spectral composition of the light given by the lamp, which is exceptionally white for an incandescent lamp, approaches sunlight very closely.

TANTALUM LAMP.—Lamps having filaments composed of the rare metal tantalum are manufactured by the firm of Siemens and Halske; the high temperature of incandescence attained results in a consumption of energy of only about 1·5 to 2 wpcp. The filament, being oxidisable, must be enclosed in a vacuum. As at present manufactured, the filament consists of a finely-drawn tantalum wire.

OSMI LAMP, a trade name for one variety of tungsten lamp (see above).

OSMIUM LAMP, an incandescent lamp in which the filament is composed chiefly of the rare metal osmium. This lamp is the invention of Dr. Carl Auer von Welsbach.

OSRAM LAMP, a trade name for one variety of tungsten lamp (see above).

MULTI-FILAMENT LAMP.—Incandescent lamps have been constructed in which a number of filaments are mounted in a single globe. This may be with the object of producing a h pr and high cp lamp; in this case the filaments are mounted permanently in series. Otherwise the filaments may be mounted in parallel, and provided with an arrangement by means of which one or more may be put in circuit at will; thus affording a gradation in the amount of light available. Multi-filament construction is frequently employed in metallic-filament lamps for h pr or high cp or both. The construction is useful in these cases, since, owing to the low specific resistance of the material employed, a great aggregate length is required between terminals, even when the section employed is as fine as practicable. Metallic filaments have also been placed in series with carbon filaments in the same bulb, so as to produce an efficient lamp having an adequately high resistance.

IRIDIUM LAMP, an incandescent electric lamp the filament of which is composed of the rare metal iridium. Such lamps have been made by Gülcher, the filament being prepared by a pasting method. At present they are said to have been chiefly designed with a view to use for small pd, and are not yet available in large quantities on a commercial scale.

ZIRCONIUM OR ZIRCON LAMP, an incandescent electric lamp the filament of which is composed of the rare metal zirconium, or the carbide of zirconium. Lamps having filaments of zirconium or of a compound of zirconium (which see) do not appear to be produced on a commercial scale at present.

Deterioration of Incandescent Lamps

By this term is meant the falling-off in cp of glow lamps during the course of their life. It is chiefly due to four causes:—

1. Blackening of the internal surface of the bulb.
2. Decrease in the light emissivity of the filament.
3. Increase in the resistance of the filament.
4. Deterioration of the vacuum.

Ageing or Seasoning of Incandescent Lamps, the running of new lamps until their cp has attained a sufficiently constant value to enable them to be employed as secondary photometric standards. See Lamp, Fleming-Ediswan Large-Bulb Standard.

Life of Incandescent Lamps

Economical Life of Lamps is the number of hr which one lamp out of a series must be run in order that the average cost per cp per hr over the whole series, plus the cost per running hr of lamp renewals, shall be a minimum.

Useful Life of Lamps.—In the more general sense this term is synonymous with 'Economical Life'. In the more restricted sense, when applied to carbon-filament glow lamps, it is the length of time that a lamp will run before the cp falls to 80 per cent of the initial value.

The *total life* of a lamp is the time it will run before the filament breaks down.

Life Test of Incandescent Lamps, a test to determine the length of useful, total, or economical life of lamps. The tests are usually carried out either at the pressure for which the lamps are rated, or else the pressure on a lamp is so adjusted that the lamp gives initially the w per candle for which it is rated. Thus a complete test of incandescent lamps should give information not only as to the cp and efficiency of the lamps when new, but also as to the deterioration in these respects which may be expected during the 'life' (*i.e.* the time for which the lamp is in use before being discarded).

In order to test this point, one may test the initial cp and efficiency of a certain number of lamps, and then allow them to run on their normal pd for a period of 600 to 800 hr, the cp and efficiency of the lamps being tested at frequent intervals.

Target Diagram of Incandescent Lamps, a diagram for graphically representing the degree of uniformity in a batch of lamps with respect to cp and total w, or cp and w per candle. Each lamp appears as a dot on the paper. The diagram generally contains an area representing the limits within which all lamps should fall.

Smashing Point.—The running cost of electric incandescent glow-lamp lighting is made up of the cost of energy and the cost of lamp renewals. During its life, an incandescent lamp becomes gradually less efficient, and, provided that the lamp does not fail, a time comes when, from motives of economy, it is better to discard the lamp and bear the cost of renewal. This point, which naturally depends both upon the cost of energy and of renewals in the particular circumstances under consideration, is termed the *smashing point*. (See Ayrton and Medley, Phil. Mag., vol. xxxix, 1895, p. 389.)

Overrunning of Glow Lamps.—*General meaning*.—The application of excess pressure to glow lamps.

Restricted meaning.—The testing of lamps by the application of excess pressure, with the object of shortening the ordinary life test.

Rated Candle Power, the cp assigned to lamps after manufacture, assuming that they are run at their rated pressure. See also Rating of Lamps.

Rated Voltage, the voltage assigned to lamps at which they are supposed to give their nominal cp, and yield a definite cp per w consumed. See also Rating of Lamps.

Rotation of Glow Lamps in Photometry, a method of obtaining the mean cp of a lamp in a given plane by spinning it about its axis whilst readings are being taken.

Bulb, the exhausted glass envelope which surrounds the filament of an incandescent electric glow lamp.

Leading-in Wires of Glow Lamps, conducting wires which are welded into the base of the glass bulb of an incandescent lamp, and serve to convey the current from the holder to the filament. Such wires are usually made of platinum, since the coefficient of expansion of that metal is almost exactly the same as that of glass. The substitution of specially-enamelled thin copper strips has recently been proposed.

See also FILAMENT; CAP OF INCANDESCENT LAMP; LAMP HOLDER; LAMP, TUBULAR. (Ref. 'Electric Lamps', Solomon; 'The Art of Illumination', Bell; 'Radiation, Light and Illumination', Steinmetz.) [L. G.]

Lamp, Inefficiency of. See INEFFICIENCY OF ELECTRIC LAMP.

Lamp, Spherical Reduction Factor of. See SPHERICAL REDUCTION FACTOR OF LAMP.

Lamp, Tubular.—Lamps of this kind may be divided into two classes—those in which light emanates from the incandescent vapour of metals, and those in which it emanates from the luminescence of rarefied gases. The tubes are either of glass or quartz.

VAPOUR TUBE LAMP.—By this term is understood a type of tubular lamp in which the luminescence of enclosed metallic vapour is utilised for the production of light. The only practical existing examples of this are the mercury-vapour lamps, of which there are different kinds on the market.

MERCURY-VAPOUR LAMP.—The light from an enclosed intermittent stream of mercury was utilised by Way in 1860, and by Rapieff in 1879. Subsequently Arons and Cooper-Hewitt, Steinmetz, and others devised tubular lamps 1 m and more in length, in which a stationary anode was employed, and the luminescence of mercury vapour at a very low pressure was utilised. More recently, attempts have been made to employ a smaller tube and higher internal pressure, with, it is claimed, improved results.

Mercury lamps are undoubtedly very efficient. The chief difficulties militating against their general introduction have been the starting of the lamp, and the unpleasant colour of the light derived from it. See also 'Vogel Arc Lamp' under LAMP, ARC.

COOPER-HEWITT LAMP.—This lamp is one of the best-known mercury-vapour lamps, the light being produced by the luminescence of enclosed mercury vapour under a l pr when excited by the passage of an electric current.

In order to start the lamp it is usually necessary to incline the tube so that a mercury arc is formed which gradually extends along the tube. The tipping was formerly done by hand, but an electromagnetic tipping arrangement has also been employed. Other methods of starting the lamp have been devised, *e.g.* the momentary production of a sufficiently high pd across the terminals of the lamp to spark across the intervening space.

The most efficient results with this type of lamp are said to be obtained with a fall of potential of from 0·3 to 0·5 volt per cm length of tube. In order to utilise a high pd a considerable length of tube is therefore necessary, or else a number of lamps must be run in series.

The efficiency of such lamps has been variously given as from 0·3 to 0·8 wpcp.

BASTIAN LAMP, a compact form of mercury-vapour lamp in which a winding tube of comparatively small dimensions is employed, the lamp being started by an electromagnetic rocking device.

QUARTZ LAMP.—Recent improvements in the manufacture of quartz glass by Heræus have enabled this glass to be employed for the envelopes of mercury-vapour lamps. The quartz glass is capable of withstanding a high temperature, and this enables the energy consumption allowable for mercury lamps of given dimensions, to be increased, leading, it is said, to improved efficiency. Quartz glass has also the property of being very transparent to ultra-violet rays. Lamps in which this glass is employed have been termed *quartz lamps*.

KÜCH LAMP.—In this lamp quartz glass is employed, with the result that the temperature of the luminescent mercury can be allowed to rise to a much higher value than is possible in the case of a mercury lamp employing glass of the ordinary variety. As a result, the tube of the lamp can be reduced to very moderate dimensions (about 15 cm long) even for a pressure of 200 volts, while the efficiency and spectrum of the lamp are both improved. (Ref. Bussmann, E.T.Z., 1907, vol. xxxviii.)

HERÆUS LAMP, a special form of quartz mercury lamp constructed by Heræus with the object of producing ultra-violet light. The spectrum of luminescent mercury is rich in ultra-violet rays, which are almost entirely absorbed by glass of the ordinary description. Hence the Heræus lamp is a powerful source of radiation of these rays, and is said to be of great value for medical and photographic purposes.

UVIOL LAMP, a mercury lamp in which the enclosing envelope is made up of 'Uviol glass'—a special glass due to Zschimmer, which is nearly as transparent to ultra-violet light as quartz glass, and is said to be cheaper and easier to manufacture. The lamp is claimed to be chiefly of value in cases in which powerful ultra-violet light is desired, *e.g.* for medical and photographic purposes.

FLUORESCENCE - LIGHT LAMP, a form of 'Uviol' mercury lamp in which the visible radiator is largely suppressed. The ultra-violet rays, however, are freely produced, so that many objects become visible by the rays of the lamp by means of excited fluorescence.

VACUUM-TUBE LAMP.—This term is generally used to describe those lamps in which the luminescence of a rarefied gas, as opposed to a metallic vapour, is used.

Such lamps represent a development of the old Geissler tube (which see). Tesla in 1891, and Moore in 1896, described tubular lamps of this description. At that time, however, they were only in the experimental state. The subsequently developed tubular MOORE LAMP, in which a ht discharge through nitrogen or other gases is utilised, appears to have good prospects of reaching a practical stage. See CROOKES' TUBE; VACUUM TUBE; HITTORF'S TUBE; GEISSLER TUBE. [L. G.]

Lamp Holder. — The BAYONET LAMP HOLDER is for use with lamps provided with a bayonet cap (see under CAP OF INCANDESCENT LAMP). It consists of two insulated brass spring-plungers which are connected with the source of supply, and

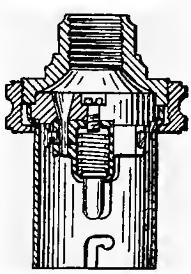


Fig. 1.—Lamp Holder

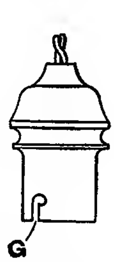


Fig. 2.—Lamp Holder

which press upon two brass contacts, as shown diagrammatically in fig. 1. The plungers are usually embedded in porcelain, and the porcelain base in which they are embedded is mounted in a brass ring, equipped with two diametrically opposite grooves, one of which is shown in fig. 2 at G. The two brass pins in the bayonet cap fit into these two grooves, and the lamp is thus held in position, the contact pieces in the cap being at the same time held in contact with the spring-plungers in the holder.

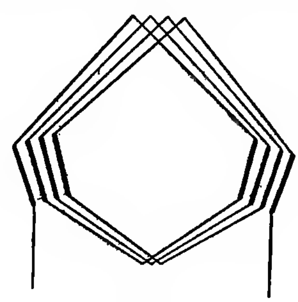
EDISON SCREW LAMP HOLDER, the form of lamp holder for use with lamps provided with an Edison screw cap. This consists of a threaded-brass hollow tube into which the cap is screwed, this brass tube being connected with one pole of the supply leads. The other connection is made by means of a brass stud which is brought into contact with the base of the cap as the latter is screwed into the holder. The outer threaded brass sleeve is insulated, and is kept in position by means of a porcelain ring. The Edison Screw Lamp Holder is rarely used in Britain except for metallic-filament lamps of several hundred candle power.

Lamp-hour, an approximate unit of power by which has hitherto generally been implied the amount of power consumed by one 8-candle lamp burning for 1 hr. In view of the present tendency to employ lamps of much greater cp, either the lamp-hour will have to be rigorously defined or the term will soon become obsolete, as it will be too indefinite to serve any useful purpose.

Lancashire Automatic Reversible Booster. See BOOSTER, REVERSIBLE.

Langsdorf and Begole Frequency Meter. See FREQUENCY INDICATOR OR METER.

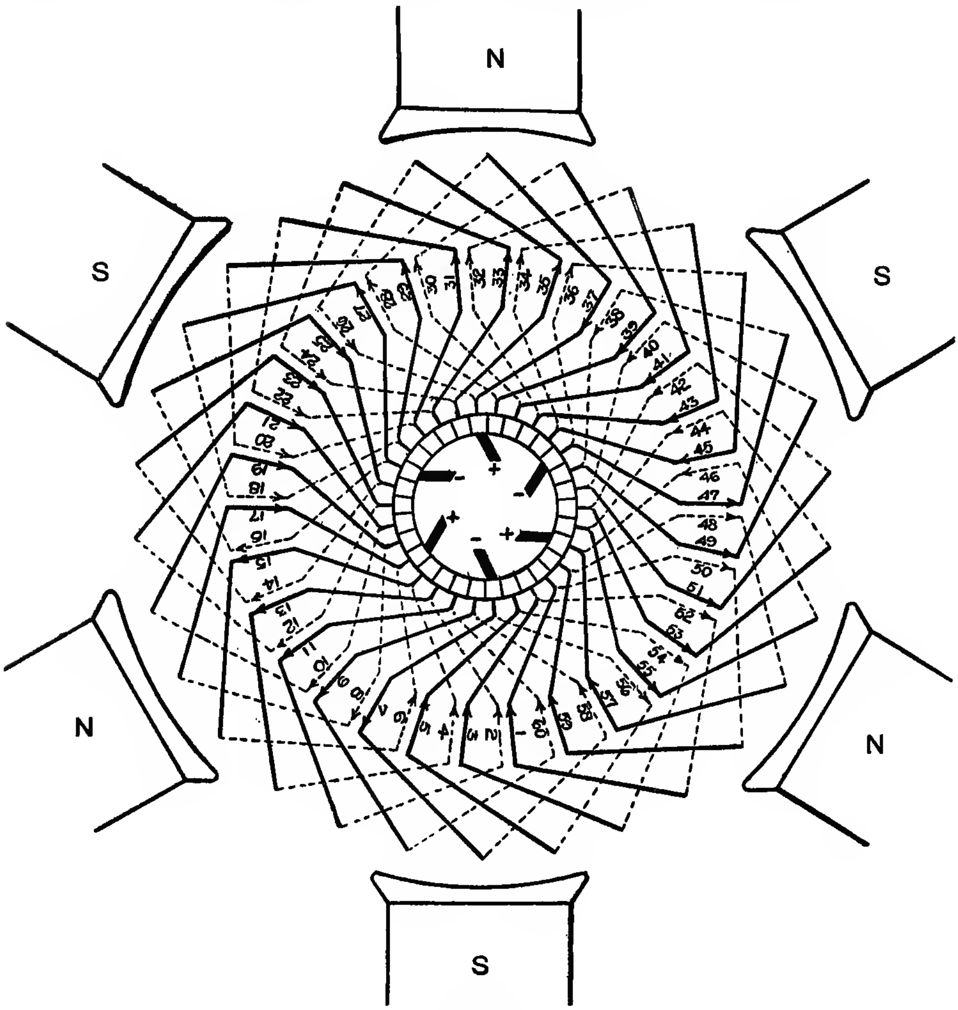
Lap Coil, one in which each turn or group of turns is exactly like every other



Lap Coil

turn or group of turns, and therefore overlaps the others, as distinguished from a spiral coil (which see). See fig.

Lap Winding.—(1) In ac generators and motors, a winding composed of lap coils; (2) In cc generators and motors, a term frequently employed for the variety of winding preferably designated as multiple-circuit winding (which see). The two chief classes of cc windings are preferably designated as multiple-circuit windings and two-circuit windings, but they were formerly more usually termed lap windings and wave windings, and these terms are still widely used. A lap winding for a cc machine is shown in



Lap Winding

the fig. For a concise treatment of armature windings, see 'Armature Construction', Hobart and Ellis.

Latent Heat. See STEAM.

Lathe for Banding Armatures. See ARMATURE BANDING LATHE.

Launch, Electric. See ELECTRIC LAUNCH.

Lava Insulation. See INSULATION, LAVA.

Lavite Insulating Material, a hard, light, buff-coloured insulating material, closely resembling 'lava'. It has a good dielectric strength, and is said to be unaffected by any temperature lower than 1000° C. It is moisture- and acid-proof, and can be manufactured in almost any form. See also INSULATION, LAVA.

Law, Baur's. See under ELECTRIC BREAKING STRENGTH.

Law, Becquerel's. See BECQUEREL'S LAWS OF THERMO-ELECTRICITY.

Law, Cosine, or Lambert's Law.—This law asserts that the intensity of illumination of a surface is proportional to the cosine of the angle of inclination at which the rays of light strike the surface. The law is only strictly true in the case of a theoretically perfectly diffusive surface. Matthews, for instance, found that when the angle of incidence was very great, deviations from the law occur in the case even of plaster of Paris surfaces. (Ref. 'Praktische Photometrie', Liebenthal, p. 84, and other works.) See ANGLE OF INCIDENCE.

Law, Coulomb's. — Coulomb's law of electrostatic attraction and repulsion state that the force of attraction or repulsion between two charged bodies is proportional to the magnitude of the charges, and inversely proportional to the sq of the distance between them. In other words, if there be two particles whose charges are m_1 and m_2 units respectively, and if they are placed d cm apart, then the force on either will be

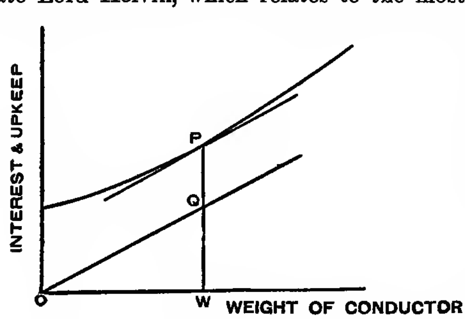
$$\frac{m_1 m_2}{d^2} \text{ dynes.}$$

If the charges be of the same polarity, they will repel, and if of different polarities, they will attract. Coulomb constructed the torsion balance, and experimentally verified these laws. See REPULSION; LAW OF INVERSE SQUARES.

Law, Fechner's, as usually expressed, states that 'variation in sensation is proportional to the logarithm of the ratio of the stimuli producing the change'. As a consequence of this law, the percentage change of illumination which can be detected by the eye is a constant over the range of illumination to which the law can be said to apply. The value of this constant percentage variation, which has been variously estimated at from about 0·5 to 1·0 per cent, has been termed *Fechner's constant.*

Law, Joule. See JOULE'S LAW.

Law, Kelvin's, a law enunciated by the late Lord Kelvin, which relates to the most



Kelvin's Law

economical size of conductor to employ in any given case for the transmission of electrical energy. The law states that, on the assumption that the cost of the line, completely installed, is proportional to the weight of metal in the conductor, the most economical size of conductor to employ is that with which the annual cost of the energy lost in the line is equal to the cost of interest and depreciation.

The assumption of proportionality between cost of metal in conductor, and the total cost, is not justified in practice; but this may be allowed for by the following device. Draw a curve connecting the weight of conductor with the annual cost of installed line (*i.e.* interest and upkeep). This will be of some such shape as shown in the fig. For a weight of copper under consideration, represented by the point W, draw an ordinate W P, and a tangent to the curve at P. Draw O Q parallel to the tangent. Then the most economical size of conductor is that which makes W Q equal to the annual value of energy wasted.

The size of conductor deduced in accordance with the above law depends on the average load to be carried by the line. In cases, therefore, where the load is more or less intermittent, the conductor may work out too small to safely carry the maximum current, and must, in such cases, be increased.

[R. C.]

Law, Kirchhoff's. See KIRCHHOFF'S LAWS.

Law, Lambert's. See LAW, COSINE.

Law, Lenz'.—Lenz, in 1834, enunciated the law that 'in all cases of electromagnetic induction the induced currents have such a direction that their reaction tends to stop the motion which produces them' (p. 466 of Prof. S. P. Thompson's 'Electricity and Magnetism'). Prof. Thompson states that Lenz' law 'is a particular case of the more general law, applicable to all electromagnetic systems, namely, that every action on such a system, which, in producing a change in its configuration or state, involves a transformation of energy, sets up reactions tending to preserve unchanged the configuration or state of that system'.

Law, Ohm's. See OHM'S LAW.

Law, Right-handed Screw.—If a current is flowing in a circuit in the direction in which a right-handed screw is turned, the magnetic force will be in the direction in which the point of the screw advances. The screw is supposed to be placed along the lines of force. See CORKSCREW RULE;

AMPERE'S RULE; FLEMING'S RULE; CURRENT, DIRECTION OF.

Law, Sine. See SINE LAW.

Law, Talbot's.—This law, originally due to Talbot, has been expressed by Helmholtz in the following complete form:—

'When any portion of the retina is acted upon by a periodically and regularly varying light, and when the period is sufficiently short, a continuous impression of light is produced, which is the same as would ensue if the light striking the eye in each successive interval of time were distributed over the entire period'.

This law forms the basis of the application of the rotating sector-disk to photometric measurements.

Law, Tangent. See TANGENT LAW.

Law, Voltametric, the amount of a substance decomposed by a current of electricity, and also the amounts of the products of decomposition, are directly proportional to the quantity of electricity passed through the substance. See 'Electrochemical Equivalents' under ELECTROLYSIS.

Law of Inverse Squares (as applied to photometry).—This law is of general application to radiant energy, but finds an important application in photometry and illumination. The law may be enunciated as follows. The intensity of illumination of any surface is inversely proportional to the distance of the surface from the illuminating source. The law forms the basis of most photometric measurements. See also LAW, COULOMB'S.

Law of Volta.—Volta showed that if a number of cells, each consisting of zinc and copper (or other metal) in a liquid, be joined together in series, *i.e.* the connecting wires being from zinc to copper in every case, the emf (hence called *voltage*) is much greater than that of one cell, and may be increased proportionally by the addition of more cells.

VOLTA'S LAW OF GALVANIC ACTION.—The difference of potential between any two metals is equal to the sum of the differences of potential between the intervening metals in the electrochemical series. See 'Electrochemical Series' under ELECTROLYSIS.

Laws of Electrolysis. See ELECTROLYSIS.

Lay (of a cable), is the length, measured parallel to the cable axis, that one wire covers while making one complete turn round the centre of the core. The Cable Makers' Association adopts a standard length of lay as twenty times the pitch diameter (which see).

Laying Cable, Solid System of. See SOLID SYSTEM OF CABLE LAYING.

Lb, the preferable abbreviation for *pound*.

Lead (chemical symbol = Pb), a metal quite extensively employed in the electrical industry as a covering for cables, as also in accumulators (which see). Its specific gravity is 11·4; its melting-point is 330° C.; its specific heat, 0·032. Its specific resistance at 0° C. is 20 microhms per cm cube, and its resistance increases by 0·4 per cent per degree Centigrade increase in temperature. The market price of lead is about £13 per ton. See LEAD SHEATHING.

Lead, Angle of. See ANGLE OF LEAD.

Lead, Return. See RETURN LEAD.

Lead, Service. See CABLE, SERVICE.

Lead Accumulator. See ACCUMULATOR.

Lead-burning Apparatus for Accumulators, an outfit for melting together the plates of adjoining cells to the intervening channel bar, consisting of (1) the generator, in which hydrogen gas is made by mixing strong sulphuric acid with broken zinc spelter; (2) the containing tank; (3) the safety pot, a device for preventing back-firing while lead-burning; and (4) an air pump. The proportions of hydrogen gas and air supplied to the flame are regulated by means of a tap called a *breechcock*, and the junction pipe fitted with taps to which the gas and air pipes of the burning apparatus are attached is called a *breeches pipe*. The pipe attached to the tubing leading from the junction-pipe is called a *finger pipe*. See ACCUMULATOR.

Lead Peroxide (PbO_2), the active material on the positive plates of an accumulator. See ACCUMULATOR.

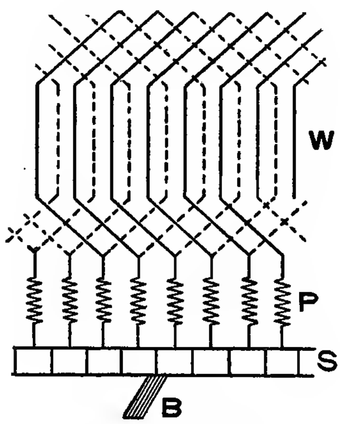
Lead Sheathing, a covering of lead over the insulation of a cable to render it impervious to moisture. Rubber-insulated cables are occasionally lead-covered; paper-insulated cables invariably so. The lead affords a small measure of mechanical protection also, but steel tape or wire armouring is generally added if mechanical injury is feared. The lead covering is usually laid on the cable by a special hydraulic press. See also CABLE, UNDERGROUND; LEAD. (Ref. 'Distribution of Electrical Energy', J. F. C. Snell; 'Modern Electric Practice'.)

Leading Current. See CURRENT, LEADING.

Leading - in Wires of Glow Lamps. See LAMP, INCANDESCENT ELECTRIC.

Leading Pole Tip or Pole Horn. See POLE TIPS.

Leads, Preventive Resistance, leads of relatively high resistance through which the commutator segments of an ac motor are connected to the winding. The object of proportioning these leads to have high resistance is to restrict the flow of current in those coils of the winding which, at any instant, are short-circuited under the brushes. The arrangement is shown diagrammatically



Preventive Resistance Leads

in the fig., in which B is a brush bearing on the commutator S; W is the winding and P are the preventive resistance leads.

Leakage, Belt. See 'Dispersion Coefficient' under DISPERSION, MAGNETIC.

Leakage, End. See END LEAKAGE; 'Flank Dispersion' under DISPERSION, MAGNETIC.

Leakage, Magnetic. See MAGNETIC LEAKAGE.

Leakage, Slot, the leakage of magnetic lines across the slot opening; the number of magnetic lines which pass down the length of the slot instead of along the teeth, the number of such lines increasing with the saturation of the teeth. See DISPERSION, MAGNETIC; INDUCTANCE, SLOT.

Leakage, Surface, the phenomenon of slight uncertain conduction across a surface, giving a false insulation resistance. It is usually due to the condensation of moisture or to the accumulation of dirt on the surface of a material.

Leakage Coefficient. See FLUX, LEAKAGE.

Leakage Cut-out, Wallis-Jones. See WALLIS-JONES AUTOMATIC EARTH-LEAKAGE CUT-OUT.

Leakage Factor. See FLUX, LEAKAGE.

Leakage Field. See FLUX, LEAKAGE.

Leakage Flux. See FLUX, LEAKAGE; MAGNETIC LEAKAGE.

Leakage Indicator, an instrument for detecting (and sometimes measuring) the leakage to earth or the insulation of a line or network; variously called *ground or earth indicators or detectors.* For systems not permanently earthed anywhere, these instruments are nearly all based on a measurement of the pd between each pole and earth, two measurements being required for two-wire systems, and three for three-wire, whether cc, single-phase, or polyphase. In the case of cc systems the insulation, both of the network and of the individual lines, can be calculated from the readings; but with ac the disturbance due to capacity effects is usually too great. In any case, however, the main showing the smallest pd to earth must be taken as being the worst insulated.

For lt systems moving-coil (for ac) or moving-iron instruments (for cc) are the most used; while for ht systems electrostatic voltmeters (see VOLTMETER) are to be preferred. On systems having some point permanently earthed at the station (*e.g.* the *neutral wire* of a cc system, or the neutral point of a three-phase system) an ammeter connected in the *earth wire* will serve as a rough guide. It should indicate no current so long as the insulation is in a satisfactory state, but on the occurrence of an earth it will at once show a deflection. The indications are, however, often misleading, and serve more as a warning than anything else. See WALLIS-JONES AUTOMATIC EARTH-LEAKAGE CUT-OUT.

Leakage Winding. See PARSONS AND LAWS' LEAKAGE WINDING.

Leatheroid, sometimes termed *leather paper* or *fishpaper*, the trade name of a tough, fibrous material supplied in thicknesses up to about 0·050 in (*i.e.* some 1·3 mm). It is manufactured in sheets, each approximately 0·004 in (0·1 mm) thick, which, to make the greater thicknesses, are adhered together under pressure. Leatheroid depends for its flexibility on the moisture it contains, and if completely dried out, it becomes brittle. It has a fairly smooth surface, and is often used for slot linings on account of its good mechanical properties.

Leather Paper. See LEATHEROID.

Leblanc Amortisseur. See AMORTISSEUR; DAMPER; DAMPING GRID.

Le Carbone Brush. See BRUSHES.

Le Chatelier Pyrometer. See PYROMETER, ELECTRIC.

Leclanché Battery. See BATTERY, PRIMARY.

Leeds and Northrup Potentiometer. See POTENTIOMETER.

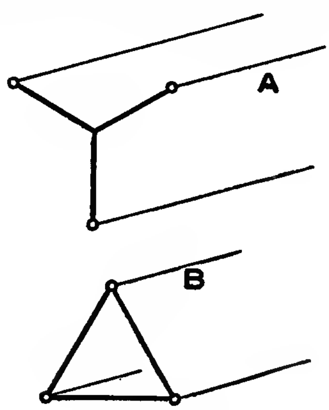
Legal Ohm. See OHM.

Legal Standard of Resistance. See RESISTANCE, STANDARD.

Legal Standard Wire Gauge (abbreviation, LSWG, or SWG). See WIRE GAUGE.

Legal Volt. See VOLT.

Leg of Circuit, a term applied usually in three-phase work to denote one of the three



Leg of Circuit

A, One leg of transmission line of Y-connected three-phase circuit. B, One leg of transmission line of Δ-connected three-phase circuit.

sp circuits, which make together a three-phase mesh or star. The words 'branch' or 'phase' are also used for the same meaning. In three-phase transformers of the core type the word 'leg' is also applied to denote a single member of the triple-legged core. The three legs of Y-connected and of Δ-connected three-phase circuits are shown in the fig.

Lenz' Law. See LAW, LENZ'.

Leonard Photometer. See PHOTOMETER, INTEGRATING.

Lever-type Brush Holder. See BRUSH HOLDER.

Leyden Jar, a glass vessel partially coated inside and out with conducting material. The thinness of the dielectric (the glass walls of the vessel) in comparison with its area makes possible the collection of a considerable electric charge on the coatings, although their difference of potential may be moderate. The principle was discovered at Leyden in Holland in the attempt to charge a glass of water, in which case the water formed the inner and the hand the outer conducting coating of the jar. See CONDENSER, ELECTRIC.

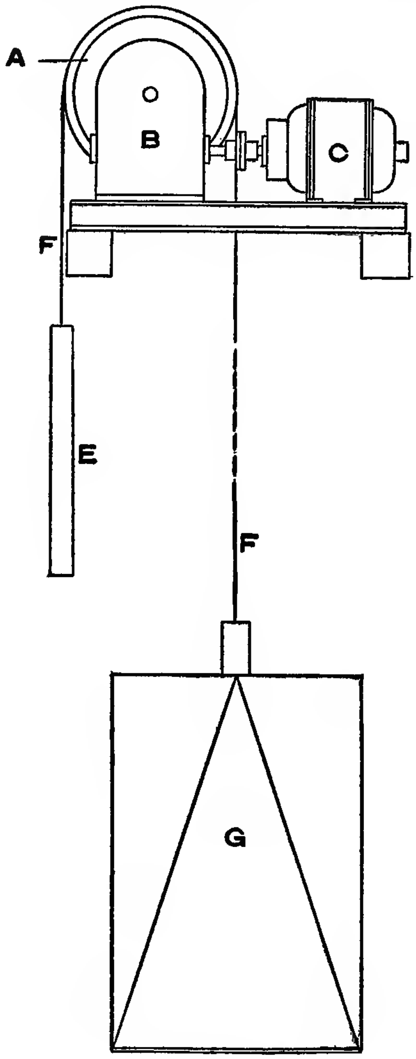
Lf, the preferable abbreviation for *low frequency.*

Lichtenberg Figures. See DISCHARGE, ELECTRIC.

Liconite, the trade term for a recently invented insulating compound of a bituminous character. It is claimed that it possesses the main advantages of rubber and gutta percha, and that it is much superior to bitumen for electrical purposes. It can be adopted for a variety of purposes, but its chief use has been for the insulation of cables. It is claimed that the material is so tough and non-hygroscopic that h pr paper-insulated cables impregnated with 'Liconite' need no lead covering. The paper is impregnated before being wrapped on the core, and several cables insulated in this way, with only a braided covering as a mechanical protection to the insulation, are stated to have withstood severe mechanical and electrical tests. The cost of h pr cables insulated with 'Liconite' is much lower than that of paper-insulated lead-covered cables. Several tests on lengths of cable immersed for a considerable time in water are stated to have proven satisfactory. 'Liconite' can also be employed as a filling for joint boxes and similar purposes. See BITUMEN. (Ref. Elec. Rev., vol. lxii, p. 907, May 29, 1908.)

Life Test of Incandescent Lamps. See LAMP, INCANDESCENT.

Lift, Electric.—An electric lift is an appliance whereby, by means of electric power, passengers or goods are conveyed from one level to another. It comprises a cage suspended by wire ropes between upright guides in a rectangular chamber, known as a lift-well, extending from top to bottom of the building in which the lift is placed. The wire ropes pass over a guide pulley at the top of the lift-well, and are led by other guide pulleys to the drum of an electric winding gear by which the cage is lifted or lowered. In some cases, as shown in the illustration, the winding gear B C is placed at the top of the well, and the suspension ropes F pass directly round the drum A, no guide pulleys being employed. A balance weight E equal to the weight of the cage G, plus half the average load, is also suspended by wire ropes between guides at one side of



Electric Lift

the lift-well, the suspension rope being led to the winding drum, and so arranged that as the cage is lifted the balance weight is lowered, and vice versa. The motor C drives the drum A by means of a worm gear at B.

WINDING GEAR.—In some makes of winding gear there are two drums, the one taking the cage rope and the other the balance rope; and the one winding in while the other pays out. In other makes the balance weight and cage are secured to opposite ends of the same ropes, which pass over the winding drum in V grooves which have sufficient grip to drive the ropes. Both systems appear to be very satisfactory, and both are claimed by their respective makers to be the best. As it is usually necessary that lift gears should work silently, worm gearing is employed to transmit the power from the motor to the winding drum. Three principal methods are in use by which a person in the cage can start, stop, and reverse the winding gear.

PULL-ROPE SYSTEM.—The first and simplest arrangement consists of an endless rope, one part of which extends from top to bottom of the lift-well and passes through the cage, the other part being led round guide pulleys in any position required. This rope is attached at some convenient place to the handle of the winding-gear controller switch, so that the person in the cage can, by pulling the rope, start the cage in either direction, and stop it at any required point.

CAR-SWITCH SYSTEM.—In the second arrangement, known as the car-switch system, a flexible cable is led from some convenient point in the lift-well to the cage, sufficient slack being left to allow free movement. The cable makes connection between a small two-way switch in the cage and two magnets or solenoids or other arrangements, which cause the controller to start the gear in one direction or the other, according as the two-way switch is turned to the right or left, the gear stopping when it is placed in mid-position.

PUSH-BUTTON SYSTEM.—In the third arrangement, known as the push-button system, the gear may be operated either by a person in the cage or at any of the floors. A push-button is placed at every floor, and a number of push-buttons equal to the number of floors is placed in the cage. These push-buttons are connected by flexible and other leads to suitable magnetic arrangements on the lift controller. The operation of the cage is as follows. Suppose a person on the second floor wishes to proceed to the fourth floor, the cage being at the time at the ground floor. He presses the button and the cage ascends, stops automatically at the second floor, and unlocks the lift door. The passenger enters the cage, closes the door, and presses the button marked 4 in the cage. If the door is properly closed, the pressing of the button locks the door, and the cage starts for the fourth floor. If the door is not properly closed, the cage will not start. On arrival at the fourth floor the cage stops and unlocks the lift door. The arrangement of connections is somewhat complicated, but it will be seen that it does away with the necessity for a lift attendant. A disadvantage is that if a careless passenger leaves a door open, the lift is put out of service except for that particular floor.

CONTROLLERS.—As it is essential that electric motors should have resistance in their circuits when starting, and that this resistance should be gradually cut out as they speed up, and as it is impossible for this gradual cutting-out of the resistance to be performed by the person in the cage, some automatic means must be provided for doing it.

A lift controller contains three essential parts: (1) a main switch to close and open the circuit; (2) a reversing switch to control the direction of running of the winding-gear motor; (3) a switch and resistance with a suitable number of contacts. On either of the foregoing systems the switches 1 and 2 are worked from the cage, while 3 has to be worked automatically. Some of the methods used are as follows:—

1. The switch-arm is driven round by a falling weight, the speed being controlled by a dash-pot. This arrangement is only suitable for the pull-rope system. Pulling the rope to start frees the weight, and pulling it to stop raises the weight and switches in the resistance ready for a fresh start.

2. The switch-arm is weighted and pulled up by a solenoid switched on by (1) or (2), the speed being retarded by a dash-pot. On breaking the circuit the weighted switch arm falls, so switching-in the resistance.

3. The switch-arm is driven by speed-reducing gear from the motor shaft, and is weighted so as to fall back when the circuit is broken.

4. The switch arm is driven by a little auxiliary motor, and falls back either by a weight or by a spring when the circuit is broken.

5. The separate sections of resistance are connected to contacts having short-circuiting switches attached to the plungers of a series of solenoids wound to operate with different pressures, and having their windings connected to the motor terminals. When (1) and (2) are closed, the motor starts, and as its speed increases, the pressure across its terminals rises. When it has risen to a certain value the first solenoid acts, short-circuiting the first section of resistance, so causing a further increase of the motor speed and pressure, which causes the second solenoid to operate, and so on until all the resistance is short-circuited. On breaking the circuit the solenoids all drop their switches, so putting in the full resistance again, ready for the next start.

In another arrangement of solenoid controller, connection to the solenoids is made and broken by a switch, moving over a series of contacts. This switch is pulled on by a solenoid, and, having a weighted arm, it drops off automatically when the solenoid is de-energised. The speed at which the switch is pulled on is regulated by a dash-pot.

SAFETY APPLIANCE.—In the motor circuit the usual fuses or circuit breakers are provided, which will act if the cage is overloaded. In the pull-rope system, buttons are attached to the rope at the top and bottom of the lift-well, the positions of these buttons being such that if the cage overruns its proper position, it catches one of the buttons, so operating the controller and stopping the gear.

In the other systems the same effect is obtained by means of electric contacts, which are operated by the cage if it overruns its proper position. Safety grips are provided on the cage which, if the ropes break, will grip the upright guides and prevent the cage from falling. See MINING EQUIPMENT, ELECTRICAL; CRANE, ELECTRIC.

[C. W. H.]

Lifting Power of Magnet, the attraction of a magnet for its armature or keeper; the force tending to draw together opposing faces of a gap in a magnetic circuit.

This attraction may be very great with large magnets, and particularly with electromagnets. It depends upon the square of the induction density occurring in the magnetic joint or space between the keeper and the pole-face or faces, as well as on the area of the opposed magnetised surfaces. When the force exerted is in the direction of the magnetic flux, then the force is approximately given by the expression $\frac{B^2}{8\pi}$ dynes per sq cm of polar area, or

$$0{\cdot}0405\left(\frac{B}{1000}\right)^2 \text{ kg per sq cm of polar area.}$$

(Ref. Thompson's 'The Electromagnet and Electromagnetic Mechanisms'.) See MAGNET, TRACTIVE FORCE OF.

Light, Arc. See ARC; ARC LIGHT; LAMP, ARC.

Light, Infra-red.—Light which lies beyond the red in the spectrum, and is therefore of too great wave length to be visible, is known as *infra-red*; the infra-red range of the spectrum may be said to consist of the portion of the spectrum of greater wave length than about 0·8μ, but the exact extent of its range is not sharply defined. This portion of the spectrum is also referred to as the '*heating*' *rays*. See also LIGHT, ULTRA-VIOLET.

Light, Mechanical Equivalent of.—By this term is understood the power which must be radiated in any direction in order that the source may have an illuminating power of one candle in that direction. The value of the equivalent thus necessarily rests upon an arbitrary physiological basis, and depends upon the wave length of the light yielded by the source in question. For approximately white light, the values determined by different observers vary from about 0·1 to 0·3 wpcp. (Ref. Drysdale, Proc.Roy.Soc. vol. lxxx, 1907.)

Light, Ultra-violet.—Light beyond the violet in the spectrum, and therefore of too small wave length to be visible, is known as *ultra-violet.* The range of ultra-violet light may be said to extend from about 0·4 μ onwards, and to consist of rays of smaller wave length than this value. This portion of the spectrum is also referred to as the *actinic* or *chemical rays.* See also LIGHT, INFRA-RED.

Light, White.—By *white light* is generally understood a light the spectral composition of which is identical with that of normal diffused daylight. The latter, however, varies at different periods of the day, and the exact spectral composition of *white light* is therefore not rigidly defined. It has been proposed that the spectrum of light from the crater of the electric carbon arc, burning under specified conditions, should be taken as a standard. Moore (Trans. Am. Ill. Eng. Soc., May 1907, p. 288) has recently proposed that the spectrum of luminescent carbon dioxide in the Moore tube (see LAMP, TUBULAR) should be adopted for this purpose.

Light Load of Machine, a term usually applied when considering loads of, say, less than one-quarter normal load.

Lighting, Arc. See ARC; ARC LIGHT; LAMP, ARC; ARC LIGHTING, RECTIFIER SYSTEM OF; 'Constant Current Generator' under GENERATOR.

Lighting, Incandescent. See LAMP, INCANDESCENT ELECTRIC OR GLOW.

Lighting and Power System. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Lighting Load. See CENTRAL STATION FOR THE GENERATION OF ELECTRICITY.

Lightning Arrester, an apparatus for providing a path by which lightning disturbances or other static discharges may pass to earth. In lightning arresters for protecting transmission lines, this provision must be attained with the minimum impairment of the insulation of the lines. Consequently lightning arresters usually comprise air gaps, resistances, and arc-suppressing devices. An excellent paper on Lightning Arresters by J. S. Peck may be found in the Journ.I.E.E., vol. xl, p. 498.

In the HORN-TYPE ARRESTER, of which fig. 1 is an illustration, two wires, after

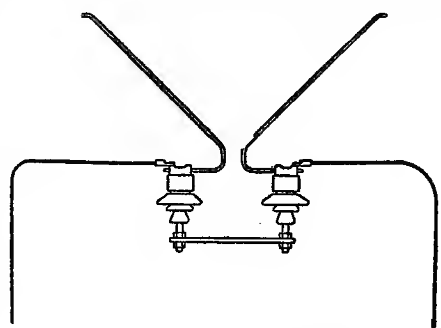


Fig. 1.—Horn Type Lightning Arrester

approaching within a short distance of one another, are bent divergently. These wires are supported on insulators. One of them is connected to the line to be protected and the other is earthed. The normal line pressure is insufficient to bridge the gap, even at its narrowest portion, but an extra h pr, whether due to lightning or to other disturbing phenomena, will bridge the gap at its narrowest point and establish a path to earth. When, however, the main current attempts to flow across, phenomena of electromagnetic repulsion force the arc upward along the horns, lengthening and attenuating it, until it finally becomes extinguished.

The NON-ARCING MULTIGAP ARRESTER is based on the principle of employing for the terminals across which the arc is formed, such metals as are least capable of maintaining an alternating arc between them. This non-arcing property of certain metals was discovered by Alexander Wurtz. A number

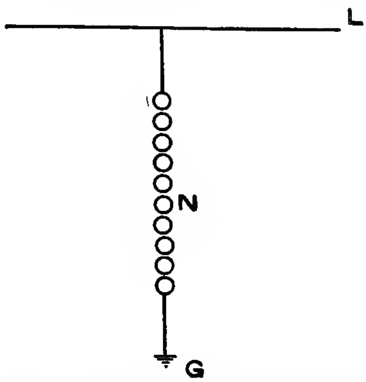


Fig. 2.—Wurtz Non-arcing Multigap Lightning Arrester

L, Line. N, Non-arcing metal cylinders. G, Earth.

of such gaps are arranged in series. A lightning arrester of this type is illustrated in fig. 2.

The LOW-EQUIVALENT ARRESTER is a type of multigap arrester in which, as illustrated in fig. 3, about half of the total number of gaps are shunted by an ohmic resistance. Prior to the occurrence of any discharge, the middle point is thus at the ground potential, and there are, between line and ground, only one-half of the total number of gaps. This is, however, sufficient to prevent a bridging of the gaps by the normal line pressure. The phenomena involved in the operation of this type of arrester are somewhat complex. It is, however, very effective, and is in extensive use.

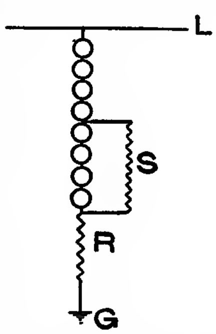


Fig. 3.—Low-equivalent Lightning Arrester

L, Line. S, Shunt resistance. R, Series resistance. G, Earth.

The MULTIPLEX ARRESTER is an arrester of the multigap type, and has been devised for the purpose of relieving the high static potential liable to exist between the different wires of a transmission circuit. Each line is provided with its multigap arrester, and the middle points of all the different arresters are interconnected by ohmic resistances.

In the WATER-JET ARRESTER, one type of which is illustrated in fig. 4, jets of water are thrown upward against plates connected with the line wires.

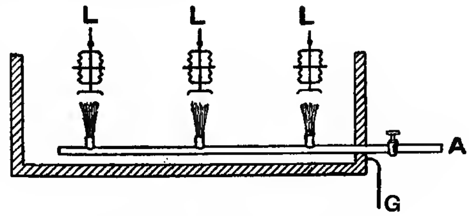


Fig. 4.—Water-jet Lightning Arrester

L, Line. G, Ground. A, Water enters.

A WATER-COLUMN ARRESTER differs from a water-jet arrester in that each line is in contact with a column of water from which a fine spray is maintained.

In WATER-DROPPING LIGHTNING ARRESTERS, each line is in contact with a suitably arranged and maintained vessel of water from which the water is discharged in a succession of isolated drops, each of which carries away with it a certain amount of static charge, thus relieving the line from the harmful consequences of accumulated charges.

The ELECTROLYTIC LIGHTNING ARRESTER is based on the phenomenon that a non-conductive film which withstands a pressure of some 400 volts is formed on the surface of aluminium when immersed in certain electrolytes. If, however, the film is exposed to a higher pressure, it is punctured by many minute holes, and its resistance is so reduced that a large current may pass. But when the pressure is again reduced, the film becomes again effective, the holes becoming resealed. In a commercial arrester, a suitable number of these aluminium cells are arranged in series with one another and with an air gap. See ALUMINIUM; CONDENSER, ELECTRIC.

WURTZ LIGHTNING ARRESTERS FOR ALTERNATING CURRENTS.—Wurtz has developed a number of ac lightning arresters in which use is made of the phenomenon that the vapour arising from certain alloys during fusion extinguishes the arc occasioning the fusion.

The following are types of lightning arresters adapted for installing on tramcars equipped with 600-volt cc apparatus.

WURTZ LIGHTNING ARRESTER FOR TRAMCARS.—Between the two terminals representing respectively ground and line, there is a gap of about 12 mm which is occupied by wood slightly carbonised on the surface. This is sufficiently conducting to afford a path for a lightning discharge, but nevertheless affords too high a resistance to affect normal operation, since the resistance between the terminals amounts to several thousand ohms. To ensure rapid extinction of the arc, the terminal electrodes are made of special alloys giving off minute quantities of metallic vapour.

AJAX LIGHTNING ARRESTER, a type of arrester for tramcars. It comprises an air gap between two brass wires sealed in a glass tube. These brass wires are parallel to each other, and are arranged at a small distance apart. The arrester contains several of these sealed units. Each lightning discharge renders one unit useless and automatically makes contact for the next. The arrester consequently has the disadvantage of requiring considerable attention in providing refill units.

GARTON LIGHTNING ARRESTER FOR TRAMCARS.—The current flowing to earth as a consequence of a lightning discharge, traverses a resistance consisting of a carbon rod. This occasions a pd between the ends of the carbon rod. This pd is caused to excite a solenoid and draw up a plunger, which increases the air gap traversed by the discharge, occasioning its suppression.

See also MULTIPLEX CONNECTION (OF A LIGHTNING ARRESTER); END-GAP STATIC; STATIC DISTURBANCES.

Lightning Phenomena. See STATIC DISTURBANCES; END-GAP STATIC.

Lilliput Arc Lamps. See 'Miniature Arc' under LAMP, ARC.

Limit Indicator. See HANDCOCK AND DYKES LIMIT INDICATOR; also CURRENT LIMITER.

Limit to Output of Dynamo-electric Machinery.—The limit to the output of an electrical machine is that beyond which working of the machine gives rise to a rapid deterioration of some of the working parts. For instance, in cc machines, when a certain load is reached, sparking occurs at the brush such that should this load be continued for any length of time the sparking becomes worse, the commutator becomes damaged, and the machine may ultimately become inoperative. In other cases it may be found that a certain part of the machine becomes unduly hot when a certain output is reached, so that the insulation rapidly deteriorates if this load is continued, and a breakdown will ultimately result. In still other cases the pressure regulation may constitute a limit to the output, and in other cases the efficiency. Machines are, of course, not rated right up to the ultimate limit of heating or sparking. See also THERMAL LIMIT OF OUTPUT.

Limiter, Current. See CURRENT LIMITER; also HANDCOCK AND DYKES LIMIT INDICATOR.

Limiting Distance of Speech, in telephony, is determined by the electrical dimensions of the circuit, *i.e.* by the capacity, inductance, and resistance. In general the capacity and resistance act adversely, and the inductance favourably. The factors concerned in determining the actual limits are so complicated that no very exact law has as yet been discovered. [J. E-M.]

Line. See LINE OF INDUCTION; FIELD, MAGNETIC; MAXWELL.

Line, Artificial, a piece of apparatus consisting of an arrangement of resistances and capacities grouped in such a fashion as to be electrically equivalent to an actual cable. Or it may consist of a specially constructed condenser whose plates are cut into a long metallic ribbon, in which case resistance and capacity are uniformly distributed along the line, and not concentrated locally, as in the former case.

Line, Kapp, a unit of magnetic flux used by early dynamo designers, being 6000 cgs magnetic units. With this unit the emf of a cc generator becomes 1 microvolt per rpm per armature conductor in series per Kapp line of total flux. This unit is now rarely employed. See MAXWELL; KILOLINE; MEGALINE; LINE OF INDUCTION; FIELD, MAGNETIC.

Line, Overhead, wires or cables of copper, bronze, aluminium, or iron, supported by insulators at a suitable height above the ground, for the purpose of conveying electrical energy from one place to another. The insulators are bolted to horizontal arms of wood or steel, carried by wooden or steel poles or towers, or else they are fixed to the walls of buildings, &c. See LINE ERECTION; LINE POLES; INSULATOR; TRANSMISSION LINE, STEEL TOWER; CONDUCTORS, OVERHEAD; CABLE, AERIAL; ALUMINIUM.

Line, Steel Tower Transmission. See TRANSMISSION LINE, STEEL TOWER.

Line Accumulator. See ACCUMULATOR.